

UNITED STATES DEPARTMENT OF AGRICULTURE

Soil Survey (Reconnaissance)
of
The Trans-Pecos Area, Texas

By

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Texas Agricultural Experiment Station

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SOIL SURVEY (RECONNAISSANCE) OF THE TRANS-PECOS AREA, TEXAS

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AREA SURVEYED

The trans-Pecos area lies in the extreme western part of Texas (fig. 1). It comprises all that part of the State lying west of Pecos River, except a small portion of Val Verde County which was included in a previous survey. It is an irregularly shaped area including nine counties, Brewster, Culberson, El Paso, Hudspeth, Jeff Davis, Pecos, Presidio, Reeves, and Terrell, and covers a total area of 31,392 square miles, or 20,090,880 acres. The area surveyed comprises more than one ninth of the State of Texas and is nearly as large as the State of Maine. Previous detailed soil surveys included in the area are Reeves County (2)¹ surveyed in 1922, and a small part of El Paso County, included in the Mesilla Valley (12), New Mexico-Texas area, surveyed in 1912.

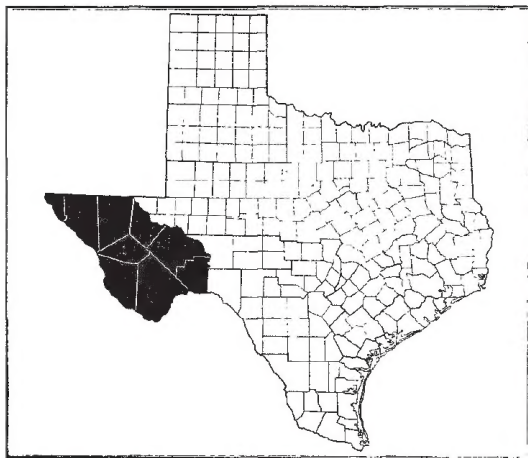


FIGURE 1.—Sketch map showing location of the trans-Pecos (reconnaissance) area, Texas.

The area lies between 102° and 107° W. longitude and between 29° and 32° N. latitude. It is bounded on the north by New Mexico, and on the east and north by Texas counties included in reconnaissance surveys of west-central Texas (4), made in 1922, and south-central Texas (11), in 1913. The Rio Grande, which forms the boundary between the United States and the Republic of Mexico, borders the area on the south and west.

The base map used in making this survey was constructed in the field with the plane table. The small scale of the map makes it impossible to show many small areas of soil. Only important soils and groups of soils are shown, though in the report the soils are described in detail and the variations of soil types and phases are discussed. Owing to the sparse settlement of the area and its rough

¹ Italic numbers in parentheses refer to Literature Cited, p. 65.

relief in many places, the county lines were located at only a few points. Many of these lines, which have never been well located, were placed on the map by drawing straight lines between the few known points.

In the southeast corner, the soil map does not fit exactly that of the south-central Texas area, owing to recent changes in soil definitions. Included areas covered in detail by previous surveys



FIGURE 2.—Topographic map of the trans-Pecos area, Texas.

were not resurveyed, but the larger soil areas were transferred to the reconnaissance map, and the smaller areas were grouped and shown in a form consistent with the plan used in reconnaissance mapping.

Figure 2 shows the topographic features of the trans-Pecos area. The greater part of the area constitutes a physiographic province different from the rest of the State. Without attempting to discuss

the details of the relationship of the various parts of the area to the great physiographic regions of the country as a whole, a matter with which the physiographer and geologist are concerned, it will suffice for the purpose of this report to state that the area includes three outstanding features—(1) plateaus, (2) more or less mountainous ridges, and (3) lowland basins.

The simplest physiographic subdivision of the area is into two parts, (1) the Edwards-Stockton Plateau and (2) the ridge and lowland section, by a line running from Pecos River, about 35 miles northeast of Fort Stockton, where the river is crossed by the northern boundary escarpment of the Edwards-Stockton Plateau, southwestward to the central part of Brewster County; thence southeastward around the Stillwell Basin and along the eastern front of Santiago and Carmen Mountains southward to the Rio Grande. South and east of this line lies the trans-Pecos part of the Edwards Plateau, locally called the Stockton Plateau. It consists of an imperfectly dissected plateau, except for a thoroughly dissected fringe a few miles wide along the Rio Grande, ranging in elevation between 2,000 and 2,500 feet above sea level. It is underlain by horizontal beds of limestone and covered by a very thin layer of stony soils.

The ridge and lowland type of physiography occupies the rest of the area and, like the Edwards Plateau type, is not confined to the trans-Pecos region of Texas but extends northward and westward beyond this region. It occupies by far the larger part of the area, all except the southeastern part. In general, the features stretch across the area in northwest-southeast belts and consist of three ridges differing in clearness of definition and extent, and four main lowland belts. The easternmost ridge, in its several parts from north to south, consists of the Guadalupe Mountains, of which El Capitan, rising to an elevation of about 9,000 feet above sea level, is the highest peak, also the highest point in Texas; Delaware Mountains; Culberson Plateau; Apache Mountains; Davis Mountains and their southward extension around Alpine; and Santiago and Carmen Mountains. The second ridge consists of the Diablo Plateau, Hueco Mountains, and Sierra Diablo on the north, succeeded southward by Van Horn, Tierra Vieja (pl. 1, A), Chinati, and Bofecillos Mountains. The third ridge consists of the Franklin Mountains, at the south end of which lies the city of El Paso. Only the south end of Franklin Mountains lies within the area.

The easternmost lowland belt consists of the Pecos Plain, constituting its largest area; the Marathon Basin, separated from the Pecos Plain by Glass Mountains; the Maravillas Valley lowland; and the Stillwell Basin. The second basin belt consists of Salt Basin at its northern end, and southward of Valentine Basin, Marfa Plateau, Alamito Valley, Green Valley Basin, and the less distinctly defined Big Bend Basin. This basin belt is interrupted by many small plateaus and hills, especially in its southern half. The third basin belt consists of Hueco Bolson at its northern end, lying immediately east of El Paso, and south of the latter city the basin is occupied by the Rio Grande in such a way that most of its area seems to lie in Mexico. At a number of places on the northeast side of the river small areas of plains may be considered as extreme eastern outliers on the United States side of the river of the Hueco Bol-

son. They include Quitman Basin, consisting really of an outlier or southern-projecting branch basin of Hueco Bolson, the Rio Grande Valley, and the Rio Grande Gravel Plain (pl. 1, B). The fourth basin is represented in the area covered by a short stretch of the Rio Grande Valley lying west of Franklin Mountains and north of El Paso.

The ridge belt consists principally of two kinds of rocks—sedimentary, mainly limestones, and igneous, mainly basaltic. Franklin Mountains and the south end of Diablo Plateau in the vicinity of Van Horn consist largely of metamorphic rocks of Paleozoic and pre-Paleozoic ages, and these rocks occur elsewhere within the area in small patches. Davis Mountains and some of the mountains south of Marfa in both of the eastern ridges consist of dark-colored igneous rocks mainly, if not entirely, volcanic, and elsewhere the ridges are underlain mainly by limestones.

Culberson Plateau is an eastward-sloping plateau terminated along the west side by a westward-facing escarpment about 1,000 feet higher than the Salt Basin west of it and a little less than 5,000 feet above sea level. This strip of rough land comprises the Delaware Mountains. The eastern boundary consists of a low escarpment, the hilly border being known as Rustler Hills. The surface of the plateau is rather thoroughly dissected. Apache Mountains consist of small detached plateau areas of the same character as the Culberson Plateau, but they are somewhat lower. They lie along the southwestern side of the main plateau. Guadalupe Mountains form a "second story" on top of Culberson Plateau, extending into Texas from New Mexico. The mountains are underlain by the same kind of rocks with the same structure as those under the rest of the plateau. The highest point rises to about 9,000 feet above sea level, which is about 4,000 feet higher than the adjacent plateau.

Davis Mountains are the highest mountains in the area. They lie mainly in Jeff Davis County but extend southward into adjoining counties. They include an area of rough country underlain by eruptive rocks, most of which are dark colored. They form a mountain mass without definite differentiation into ranges. The details of the existing relief are due very largely to erosion, but some old volcanic flows are present. The extension southward from the main mountain area consists of a number of isolated hills presenting the appearance of a severely eroded plateau which ends in a bold southward-facing escarpment bounding the north side of Green Valley and also the western side of the Marathon Basin.

Southward from the Davis Mountains the Santiago and Carmen Mountains extend as a narrow ridge to the Rio Grande. These mountains form a limestone ridge separating the south end of the eastern lowland, Stillwell Basin, from the less well-defined south end of the second basin, Big Bend Basin. Glass Mountains bound the north side of the Marathon Basin and lie at almost a right angle to the general trend of the principal mountain ridges. They are underlain by sedimentary rocks, older than the rocks underlying the Edwards Plateau.

The second ridge at its northern end consists of Diablo Plateau which ranges between 3,500 and 5,000 feet in height, slopes in general eastward, is mostly bounded by escarpments on the east, west, and

south sides, and is underlain chiefly by sedimentary rocks, mainly limestones. The northern end of the western boundary escarpment is high and known as Hueco Mountains and the southern end of the eastern escarpment is known as Sierra Diablo. Immediately south of the Diablo Plateau are a number of isolated hills and short ranges known as the Van Horn, Quitman, Eagle, Carrizo, Beach, and Baylor Mountains and Sierra Blanca. They are underlain in part by sedimentary rocks, mainly limestones, in part by old metamorphic rocks, and in part by volcanic rocks. They stand as interruptions of a plain of unconsolidated sediments of recent age, derived from the mountains themselves, which constitute Sierra Blanca Basin and Quitman Basin.

South of this group, extending along the Rio Grande, which here follows a lowland belt parallel to the general ridge trend of the region, lies a long ridge known as Tierra Vieja and Chinati Mountains, and, beyond an interruption (Alamito Valley), the Bofecillos Mountains. The Tierra Vieja Mountains are a westward-facing escarpment of igneous rocks. The Chinati Mountains are a rugged mass consisting mostly of igneous rocks. The Bofecillos Mountains are the south end of the central igneous area, the main part of which constitutes the Davis Mountains. They consist in part of the eroded igneous rock plateau and seemingly of one or more igneous rock plugs. Presidio Plateau lies east of Chinati and Tierra Vieja Mountains and constitutes an interruption of the lowland basin between the first and second ranges. It is an eastward-sloping thoroughly dissected plateau, bounded on the west at its northern end by a westward-facing escarpment, but at its southern end its western side abuts against the eastern base of Chinati Mountains.

The third, or western, ridge consists of Franklin Mountains, a narrow fragment of a broken range extending northward from El Paso to the main Rocky Mountain area. Only a few miles of the southern end of this ridge lie in Texas. It is a high narrow ridge of the Great Basin type.

All the basins separating the mountain ridge belts have a desert-basin type of surface relief. The basin floors are, with apparently no exceptions, areas of sedimentation, and, although the belts as a whole are structural, the floors are areas of accumulation or sedimentation rather than of tectonic construction. They all partake, with varying degrees of definiteness, of the character of relief of the desert basins of the Southwest, and this area constitutes the eastern limit of the conditions causing such features in the United States. The floors of the basins are high along the bases of the mountains and slope toward the axes. Where a filling of coarse material has been made, the slopes are comparatively steep, but they are rather flat where the materials are fine grained.

The most easterly of the basins consists of Pecos Basin in the north and a number of isolated and smaller basins farther south, the whole series constituting a basin belt lying between the Edwards Plateau and the first range.

The Pecos Basin, as shown on the soil map, covers the northeastern part of the trans-Pecos area. The northern end has a well-defined eastward to northeastward slope and the southern end, built of material from the Edwards Plateau and other areas of fine-grained

rocks, has a gentle northward slope. The surface is smooth with practically no dissection, the valleys of the streams crossing it cutting below the smooth level of the accumulated alluvial-fan material only in the higher parts. Such dissection is very slight, however.

The Marathon Basin is connected with the Pecos Basin by a narrow belt between Davis and Glass Mountains. The floor of the basin is smooth in the northern part, the soil material is comparatively fine grained, and the surface is nearly level. The floor of the southern part of the basin is interrupted by a number of low northeast-southwest ridges. The lowland is continued southward around the westwardly projecting ragged end of Edwards Plateau by the upper Maravillas Valley, which opens southward into Stillwell Basin. Both Maravillas Valley and Stillwell Basin are typical filled basins, with well-defined slopes from the bases of the enclosing mountains toward the axes of the basins.

The northern end of the second basin is locally known as Salt Basin. It encloses intermittent salt lakes in the northern part, hence the name. Its surface slopes from the foot of the bounding escarpments of Diablo Plateau on one side and Guadalupe and Delaware Mountains on the other. South of Van Horn it is interrupted by some isolated hills, known in the northern end as Wylie Mountains, but is continued southward as Valentine Basin and Marfa Plateau. The Valentine Basin is divided at its southern end into two branches lying east and west, respectively, of the north end of Presidio Plateau. The Valentine Basin is typical of its kind, both as regards surface relief and processes of development. The Marfa Plateau is a basin lying essentially in the Davis Mountains. Its surface has been subjected to some deposition, but the deposit seems to be thin and the material fine grained. Its surface, therefore, is not of a typical desert-basin type. South of the escarpment by which the Marfa Plateau descends to the country south of the Davis Mountain igneous rocks, the Green Valley is a typical basin with rising alluvial-fan slopes. It is interrupted southward by an isolated plateau, but the basin is continued southward as the Big Bend Basin, an area of uneven relief but containing a number of small lowland belts with typical desert-basin relief.

West of Bandera Mesa, a southward extension of the igneous rocks of the Davis Mountain type, and which may be considered as a southward projection of Marfa Plateau, the narrow Alamito Valley may be considered a part of the second lowland belt and also a connecting lowland between the second and third belts, represented along the Rio Grande southwest of Chinati Mountains by the Rio Grande Gravel Plain. The Sierra Blanca and Quitman Basins west of Van Horn may be considered part or branches of the second lowland.

The third lowland consists of Hueco Bolson, a typical desert-basin plain lying between Diablo Plateau and Franklin Mountains. South of the latitude of the south end of Diablo Plateau, Hueco Bolson is occupied by Rio Grande Gravel Plain.

The fourth lowland lies west of Franklin Mountains and is occupied, in part, north of El Paso by the Rio Grande Valley. Only the eastern part of it is on the Texas side of the river, and only the southern part lies south of the New Mexico boundary.

Water is obtained from wells over most of the lowland basins and plains. In many sections good water is obtained in the basins and plains and in mountain valleys in very shallow wells, though in places in the Pecos Plain and Salt Basin the water may contain an appreciable quantity of salts. On Edwards Plateau a good supply of water is obtained from wells several hundred feet deep, but on Diablo Plateau water is not readily found, though some is obtained from wells more than 1,000 feet deep. Good springs occur in places, most of them in or near mountains. The largest, Comanche Springs at Fort Stockton on the Pecos Plain and Phantom Lake Spring (pl. 1, C) near Balmorhea at the foot of Davis Mountains, have a large flow of water. Many other springs in some of the mountains provide good supplies of water, though some cease flowing in long dry seasons. Earthen and concrete dams constructed in low places in the basins and on the mountains hold storm water for a long time and provide water for livestock. Water sufficient for livestock is obtained in most parts of the area, many of the ranches having a number of wells from which water is pumped by windmills or engines and piped to the pastures.

NATURAL VEGETATION ²

The natural vegetation of the trans-Pecos area is varied and comprises chiefly plants characteristic of semiarid and arid regions, although some plants are typical of a subhumid and even of a humid region. As a whole, the area is devoid of large vegetation, and in basins and plains the vegetation consists dominantly either of grasses or of the so-called desert shrubs, with, in places, some salt- or alkali-indicating plants. Mountains and other rough areas are in many places occupied by grasses, accompanied in some sections by western species of oak, pine, and juniper. Throughout the area, and in many places dominating the vegetation, is a scattered growth of shrubs and woody plants of true semiarid character, such as lechuguilla, yucca, and sotol. Many of the grasses of the trans-Pecos area are species that occur abundantly much farther east in regions of greater rainfall. The character of the vegetation differs largely according to moisture conditions, and this factor is controlled very largely by the character and depth of the soils. Thus, it may be seen, a decided relationship exists between soils and vegetation.

Many of the plants provide grazing and browse for livestock. Various shrubs, such as catclaw and white brush (privet lippia), are valuable honey plants, for which purpose they are extensively utilized in places. The candelilla, or waxplant (pl. 2, A), grows abundantly in some sections, and a number of small factories utilize the plant for the manufacture of wax. Guayule (pl. 2, B), a plant containing a considerable percentage of rubber, grows in certain sections, but this plant has been largely destroyed in gathering it for use in the manufacture of rubber in a small factory at Marathon.

² V. L. Cory, range botanist of the Texas Agricultural Experiment Station, accompanied the soil survey parties, collected and identified many plants, and obtained data relating to their economic importance. He collaborated in the preparation of this chapter. Throughout the text, except in the list of plant names, the local designations of plants have been used in many cases rather than the more generally accepted popular names. This has been done for the convenience of residents of the area surveyed.

Owing to the value of much of the natural vegetation as a natural resource, the need for more information regarding its character and distribution is realized, especially of the plants used as forage and browse by livestock.

The vegetation of the trans-Pecos area remains largely unchanged from its natural distribution, although in places it has been modified to some extent by the influence of range livestock. It falls naturally into several general groups, some of which occur in communities of geographic significance which can be shown on a map, whereas other characteristic plants and associations of plants inject themselves as individuals into other communities, or occur only in small areas that cannot be outlined separately.

The following list includes the more important plants growing within the trans-Pecos area: Hairy grama (*Bouteloua hirsuta*), blue grama (*B. gracilis*), black grama (*B. eriopoda*), yeso grass (*B. breviseta*), chino grass (*B. ramosa*), grama (*B. chondrosioides*, *B. uniflora*), side-oats grama (*B. curtipendula*), buffalo grass (*Buchloe dactyloides*), curly mesquite (*Hilaria belangeri*), tobosa grass (*H. mutica*), burro grass (*Scleropogon brevifolius*), alkali saccaton (*Sporobolus airoides*), saccaton (*S. wrightii*), mesa dropseed (*S. flexuosus*), sand dropseed (*S. cryptandrus*), roughleaf muhly saccaton (*Muhlenbergia asperifolia*), wolftail (*Lycurus phleoides*), Triodia (*Triodia pilosa*, *T. pulchella*, *T. mutica*), three-awn (*Aristida glauca*, *A. pansa*, *A. ternipes*, *A. wrightii*, *A. purpurea*, *A. schiedeana*), six-weeks three-awn (*A. adscensionis*), needle grass (*Stipa tenuissima*), prairie beardgrass (*Andropogon scoparius*), silver beardgrass (*A. saccharoides*), beardgrass (*A. cirratus*, *A. feensis*), coarse weed (*Acanthociton wrightii*), globemallow (*Sphaeralcea incana*), coarse grass (*Elyonurus barbiculmis*, *Epicampes berlandieri*, *E. emersleyi*), feather fingergrass (*Chloris virgata*), tanglehead (*Heteropogon contortus*), sprangletop (*Leptochloa dubia*), saltgrass (*Distichlis spicata*), sotol (*Dasyliirion texanum*, *D. leiophyllum*), lechuguilla (*Agave lecheguilla*), creosotebush (*Covillea tridentata*), tarbush (*Flourensia cernua*), lote-bush (*Condalia obtusifolia*, *C. lycioides*) privet lippia (*Lippia ligustrina*), Wright lippia (*L. wrightii*), jointfir (*Ephedra trifurca*, *E. antisiphilitica*, *E. torreyana*), yucca (*Yucca elata*, *Y. thompsoniana*, *Y. treculeana*, *Y. macrocarpa*), tassajillo (*Opuntia leptocaulis*, *O. kleiniae*), prickly-pear (*O. sp.*), tree cactus (*O. imbricata*), catclaw (*Mimosa sp.*, *Acacia sp.*), huajillo (*A. berlandieri*), false-mesquite (*Calliandra eriophylla*), greenbush (*Viguiera stenoloba*), winterfat (*Eurotia lanata*), fourwing saltbush (chamiso) (*Atriplex canescens*), chacate (*Krameria grayi*), peabush (*Parosela formosa*, *P. frutescens*), sand sage (*Artemisia filifolia*), cenizo (*Leucophyllum frutescens*, *L. minus*, *Coldenia greggii*), sacahuiste (*Nolina texana*, *N. erumpens*), candelilla (*Euphorbia antisiphilitica*), mariola (*Parthenium incanum*), guayule (*P. argentatum*), tomatillo (*Lycium torreyi*), little buckthorn (*Microrhamnus ericoides*), picklebush (*Allenrolfea occidentalis*), snakeweed (*Gutierrezia sarothrae*), hollygrape (*Odostemon trifolius*), crotonweed (*Croton neomexicana*), ocotillo (*Fouquieria splendens*), sangrededrago (*Jatropha spathulata*), resurrection-plant (*Selaginella lepidophylla*), locoweed (*Astragalus earlei*), guayacan (*Porlieria angustifolia*), spectacle-plant (*Dithyrea wis-*

lizeni), adolphia (*Adolphia infesta*), coarse gypsum shrub (*Coldenia hispidissima*), gaillardia (*Gaillardia pinnatifida*), peppergrass (*Lepidium alyssoides*), allthorn (*Koeberlinia spinosa*), peculiar plant in Big Bend (*Hechtia texensis*), jimmyweed (*Aplopappus heterophyllus*), arrowweed (*Pluchea sericea*), ash, (*Fraxinus velutina*), hackberry (*Celtis reticulata*), Texas walnut (*Juglans rupestris*), Mexican madrone (*Arbutus californica*), desertwillow (*Chilopsis linearis*), soapberry (*Sapindus drummondii*), southwestern black cherry (*Prunus virens*), Mexican persimmon (*Diospyros texana*), sumac (*Rhus virens*, *R. microphylla*, *R. trilobata*), Mexican-buckeye (*Ungnadia speciosa*), mesquite (*Prosopis chilensis glandulosa*), screwbean (*P. pubescens*), oak (*Quercus grisea*, *Q. pungens*, *Q. emoryi*, *Q. undulata*, *Q. novomexicana*, *Q. texana*), alligator juniper (*Juniperus pachyphloea*), redberry juniper (*J. pinchoti*), cherrystone juniper (*J. monosperma*), Mexican juniper (*J. mexicana*), drooping juniper (*J. flaccida*), Mexican pinyon (*Pinus cembroides*), nut pine (*P. edulis*), western yellow pine (*P. brachyptera*), and limber pine (*P. flexilis*).

The vegetation of the trans-Pecos area may be classed in five general groups which are shown in seven divisions in figure 3. These five main groups are as follows: (1) Grassland, which is subdivided into three types; (2) mesquite—sand sage; (3) yeso—saltgrass; (4) bottom-land mixed trees and shrubs; and (5) creosote-bush—blackbrush (tarbush).

In addition, there are plant associations which cannot well be shown separately as they occur in places within the various groups outlined. These are chiefly the lechuguilla, the sotol (pl. 2, C, and 3, C), the pine, the oak, and others.

Probably about two thirds of the area is occupied by the grassland groups. Where one or more species of grass are sufficiently abundant to give character to the vegetation, the range is considered grassland. Although it may be essentially a pure stand of grasses, such as occur in tobosa-grass flats (pl. 3, A), much of the larger areas of grassland is characterized by the presence of some woody plants (pl. 3, B.) Usually two or more species of woody plants are associated in most sections of grassland, and in many places one is more abundant than the others.

The dominant growth of the mesquite-sand sage community is mesquite shrubs, with considerable sand sage in places. The plant cover is very thin and scattered, although after rains some coarse grasses and weeds, including some *Sporobolus* species, wild flax, and some *Acanthiociton wrightii*, species of *Gutierrezia*, spectacle-plant, globe-mallow, and other plants, are numerous. Occasional accompanying shrubs are yucca, canutilla (jointfir), chamiso, and lote-bush. This plant association occurs on deep sands of the Reeves and Verhalen series, and, in places where mesquite dominates, the sand is blown up around the shrubs so that only a few branches project from the mounds. The mesquite-sand sage growth occurs over the main part of Hueco Bolson which is a comparatively small part of the trans-Pecos area.

The yeso-saltgrass community of peculiar plants comprises a very sparse plant growth, probably a cover of less than 10 percent of the ground. Yeso grass occurs in places, with tussock grass (alkali

saccaton) here and there in depressions. In places, especially near salt-lake beds, there is a considerable growth of saltgrass, indicating a rather large content of salt, or alkali, in the soil. A very thin and scattered growth of stunted shrubs consists mostly of *Coldenia hispidissima*, juniper, yucca, *Krameria grayi*, sumac, cactus, and mesquite shrubs. Some chamiso, broomweed (snakeweed), *Dondia diffusa*, greasewood and burro weed (picklebush) also occur in places. This

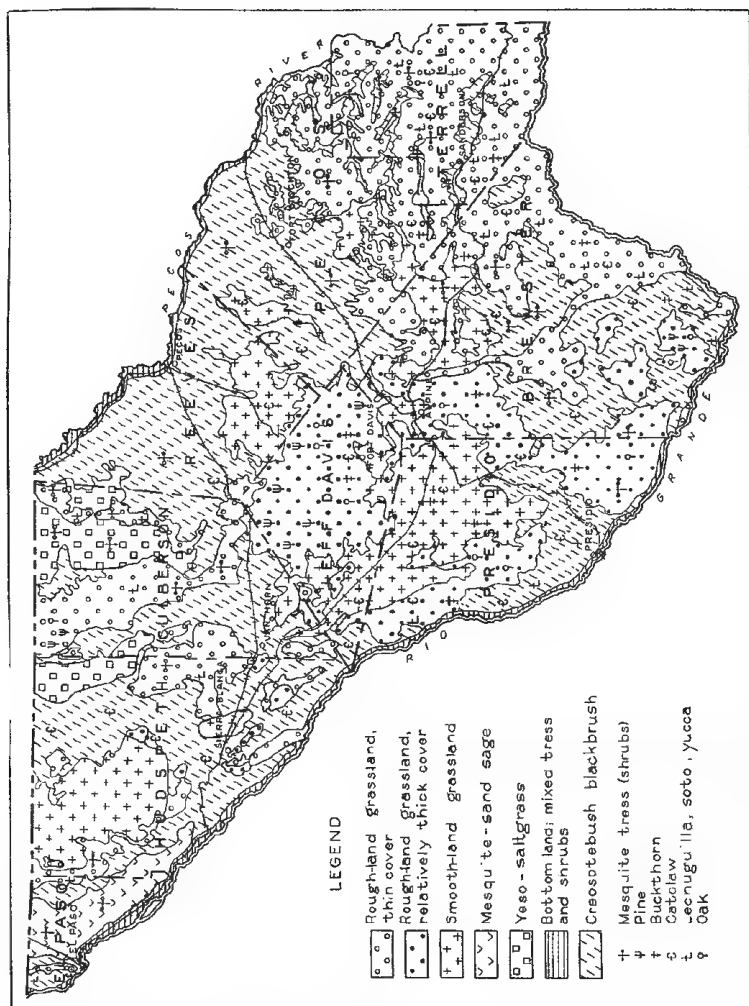


FIGURE 3.—Sketch map showing plant communities and general distribution of trees, shrubs, and woody plants in the trans-Pecos area, Texas.

type of vegetation grows entirely on areas of "gypland" in Salt Basin and on Reeves chalk on Culberson Plateau. Much of the land is bare soft gypsum with only a very slight layer of soil, but in un-eroded areas the soil may be several inches thick.

The community of plants known as bottom-land mixed trees and shrubs occurs only in the alluvial bottom lands which, in the aggregate, constitute a comparatively small proportion of the area. The

larger vegetation consists mainly of small trees of mesquite and screwbean in Rio Grande Valley, and of some oaks, walnut, wild cherry (southwestern black cherry), cottonwood, willow, and ash in the mountain valleys. In Pecos River Valley, mesquite, desertwillow, and saltcedars prevail. In addition to this growth in the river bottoms, there is a considerable growth of such shrubs as *Pluchea sericea*, and tomatillo, and some saltgrass and saccaton. In the smaller valleys many grasses of the grassland types and considerable catclaw grow. The soils occupied by this plant community are the Gila, Rio Grande, Toyah, and undifferentiated alluvial soils.

The creosotebush-blackbrush (tarbush) type of vegetation grows over probably about one third of the trans-Pecos area. It is composed mainly of the two shrubs, creosotebush and blackbrush, which are by some called desert shrubs, and a very small number of other plants occur in association with these. Creosotebush grows alone over much of the land, with very slight amounts of catclaw (*Acacia vernicosa*), ocotillo, lote-bush, and in some rougher places a scattered growth of lechuguilla and sotol, cacti, pricklypear, yucca, and here and there a clump of burro grass. Creosotebush predominates on the very shallow and very gravelly soils or in positions where soils contain the very slightest amount of moisture. Blackbrush, occurring in close association with creosotebush, chooses the deeper soils and depressions with better moisture conditions and is accompanied in many places by small amounts of burro grass, tobosa grass, tussock grass (alkali saccaton), and species of *Triodia*, with an occasional shrub, such as mesquite, lote-bush, yucca, pricklypear, and catclaw. Saltgrass, chamiso, and greasewood grow in spots of soil having considerable salt content. This type of vegetation grows chiefly on a large part of Pecos Plain; in parts of Valentine, Sierra Blanca, Salt, Stillwell, Marathon, San Francisco, and Big Bend Basins; in areas on the Edwards and Diablo Plateaus; on Rio Grande Gravel Plains; and in Alamito, Tornillos, and Maravillas Valleys. Most of the soils are moderately heavy and occupy areas in which moisture is usually very slight and in which the surface relief is mostly smooth and flat. The principal soils occupied by this growth are the Reeves.

SETTLEMENT AND DEVELOPMENT

The first settlement of civilized people in the trans-Pecos area was made by Spanish explorers from the interior of Mexico, who during the seventeenth century found Indian villages surrounded by irrigated farms on the alluvial soils adjacent to Rio Grande. Franciscan monks located missions adjacent to some of these villages and with Indian labor continued to produce crops for food. One of these missions, established in 1659, still remains in Juarez, Mexico, near El Paso, and others were located at San Elizario about 1683. Gradually Mexican settlements were established in the valley of the Rio Grande, on both sides of the river. Probably the first settlement of Americans was just at the close of the war between the United States and Mexico in 1848, when a small group of men discharged from the United States forces, together with some traders, settled on the east side of the Rio Grande near the present site of Presidio. The members of this colony engaged in trading, farming, and ranching. In 1849, Franklin (now El Paso) was a town of

about 200 inhabitants, though Juarez, just across the river in Mexico, numbered several thousand. San Elizario with 1,200 and Socorro with 300 inhabitants, chiefly Mexicans, constituted trading and agricultural centers. About this time the transcontinental trail from the Eastern States to California was established and passed through the center of the trans-Pecos area, following a course touching water holes, springs, and the Rio Grande from the Pecos River to Franklin. A branch of this trail was established, leading southward through the settlement at Presidio to Chihuahua, Mexico.

With the advent of extensive travel through the area, a number of United States Army posts were located at various points to protect travelers, mails, and freight from the Indians, and near these points there gradually grew up settlements of Americans who engaged mainly in ranching. With the extension of railroads across the area, about 1881, there was considerable increase in settlement and ranching, with some farming in places where irrigation was possible. Most parts of the area are very thinly settled, and much of the land will probably remain ranching country with few inhabitants.

El Paso and Presidio Counties were formed from parts of Bexar County in 1850 and originally occupied the greater part of the trans-Pecos area. The former was organized in 1871 and the latter in 1875. Pecos County was created from a part of Presidio County in 1871 and organized in 1875. Brewster and Jeff Davis Counties were organized from parts of Presidio County in 1887. Culberson and Hudspeth Counties were organized from parts of El Paso County in 1911 and 1917, respectively, and Reeves and Terrell Counties from parts of Pecos County in 1883 and 1905, respectively.

The population of the area is made up very largely of people from other parts of the United States, a large proportion being native-born Americans. However, there is also a very large Mexican population, many of them native born, and these predominate in the Rio Grande Valley. The population is densest near the railroads and in the river valleys, though a few people live in nearly all sections. Extensive areas show no sign of settlement other than the occasional ranch homes, many of which are located many miles from a neighboring habitation. According to the census of 1930³ the rural population averages 1.8 persons a square mile.

There are but few towns in the area. El Paso, one of the largest cities of the State, has a population of 102,421. Marfa, the county seat of Presidio County, has a population of 3,909; Pecos, Reeves County, 3,304; Alpine, Brewster County, 3,495; and Fort Stockton, Pecos County, 2,695. Van Horn, Culberson County; Fort Davis, Jeff Davis County; Sierra Blanca, Hudspeth County; and Sanderson, Terrell County, are the chief towns in their respective localities. Marathon in northern and Terlingua in southern Brewster County; Toyah and Balmorhea in Reeves County; Dryden in Terrell County; Kent in Culberson County; Valentine in Jeff Davis County; Presidio and Shafter in Presidio County; Fort Hancock, Allamore, and McNary in Hudspeth County; Sheffield and Buenavista in Pecos County; and Tornillo, Fabens, Clint, Ysleta, Canutillo, and Anthony

³ Soil survey reports are dated as of the year in which the field work was completed. Later census figures are given whenever available.

in El Paso County are important small towns and trading centers. Mexican villages lie along the Rio Grande.

Two transcontinental railroads, the Southern Pacific and the Texas & Pacific, pass through the central part of the area. The Kansas City, Mexico & Orient Railway, a part of the Santa Fe system, extends into the area from the northeast to Alpine and is now being extended to Presidio where it will connect with a Santa Fe line extending across Mexico. A line of the Santa Fe system enters the area from the north, extending to Pecos, and another line of the same system enters El Paso from the north. A short line, the Pecos Valley Southern Railway, extends from Pecos to Balmorhea. The El Paso & Southwestern Railroad extends from El Paso north, and other railroad lines extend from El Paso into the interior of Mexico. Many parts of the area lie from 50 to 75 or more miles from a railroad. Three important transcontinental highways—the Bankhead, Mexican Border, and Old Spanish Trail—cross the area from east to west and merge into one—the Bankhead—in the western part. These highways are paved through some of the most thickly settled sections. They are graded and improved and are traveled at all seasons, though in places where not surfaced they may be muddy for a short time. Other improved roads, most of which are not surfaced, extend through various parts of the area and connect the towns and more settled sections. Travel by automobile is possible over most of the roads and trails.

The area is well supplied with telephones in the more thickly settled sections, and telephone lines extend to many of the outlying ranches. Schools and churches are located in all towns and settlements. The State College of Mines and Metallurgy is located at El Paso, and Sul Ross State Teachers College is located at Alpine.

The chief industry is livestock raising. Many cattle are raised on large ranches, and in the southeastern part of the area a large number of sheep and goats are raised. General- and special-crop farming are important industries in some comparatively small areas, especially where irrigation can be practiced. The chief irrigated sections are in Pecos River Valley, Rio Grande Valley, and in the vicinity of Balmorhea and Fort Stockton. Honey production, from cultivated crops and from the natural vegetation, is an important industry in the vicinity of Balmorhea and Marathon.

El Paso, a trade and distributing center for a very large area in Mexico and in adjacent States of the United States, has a number of manufacturing industries, chief of which is one of the largest ore smelters of the Southwest, which treats ores, mainly copper, shipped from mines in New Mexico, Arizona, and northern Mexico. Packing plants for livestock products, a large cotton mill, a box factory, a cement factory, and many other manufacturing plants are located here. A small factory at Marathon manufactured rubber from the wild guayule plant for several years, but it is not in operation now. Small outdoor factories along the Rio Grande produce crude wax from the candelilla plant.

Other important industries include the production of silver at Shafter, of quicksilver at Terlingua, of ornamental building stone near Van Horn, and of petroleum from an oil field extended into the extreme eastern part of the area in Pecos County.

CLIMATE

The climate of the trans-Pecos area is mild and healthful. The long summers are characterized by comparatively high temperatures, modified, especially at night, by the high elevation of the region; by cool winters, during which occasional very cold periods occur, but ordinarily with only light snowfall; a very low rainfall; dry atmospheric conditions; a very large proportion of bright, sunshiny days; and moderate winds.

The climate is continental—that is, it is subject to great seasonal contrasts in temperature. However, the semiarid features, due to the influence of the western desert climate, together with modifications caused by the generally high elevations and some mountain areas, result in mixed climatic conditions, in which features of con-

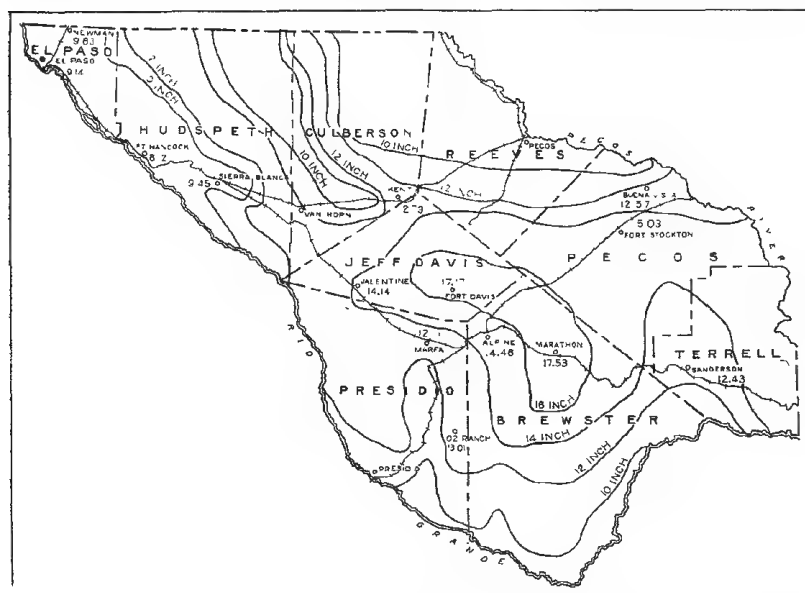


FIGURE 4.—Sketch map showing lines of equal precipitation in the trans-pecos area, Texas.

tinental, desert, and mountain-plateau types are merged, and in which some characteristics of each stand out prominently.

Temperature ranges are more regular than are the variations in precipitation. In the basins and plains the temperatures are higher in the summer, and the mean annual temperatures are also higher than in the mountain areas. Rainfall, as a rule, decreases from east to west, though it is interrupted in its trend by local mountainous areas, where the precipitation is uniformly higher than elsewhere. Figure 4 shows the lines of equal rainfall within the area.

The character of the climate is reflected distinctively in the character of the vegetal growth and in the developed characteristics of the normal soils of the region.

Table 1 gives the normal, maximum, and minimum monthly and annual temperatures at seven United States Weather Bureau Stations in the trans-Pecos area.

TABLE 1.—*Mean, maximum, and minimum monthly and annual temperatures at Weather Bureau stations in the trans-Pecos area, Texas*

Station	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Barstow: ¹	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.
Mean.....	46.4	49.7	57.5	64.1	72.2	80.8	82.2	81.4	75.6	65.2	53.8	44.9	64.5
Maximum.....	89.0	92.0	98.0	99.0	106.0	114.0	110.0	111.0	106.0	100.0	96.0	89.0	114.0
Minimum.....	-4.0	6.0	19.0	26.0	31.0	43.0	60.0	51.0	39.0	21.0	10.0	0	-4.0
El Paso:													
Mean.....	45.0	49.0	55.8	63.4	71.5	79.6	81.1	79.2	73.9	63.5	52.7	44.9	63.3
Maximum.....	77.0	86.0	93.0	93.0	102.0	105.0	105.0	103.0	100.0	94.0	85.0	77.0	105.0
Minimum.....	2.0	5.0	21.0	30.0	38.0	46.0	56.0	52.0	42.0	26.0	11.0	-5.0	-5.0
Fort Davis:													
Mean.....	43.8	48.6	55.0	62.5	70.3	74.9	75.1	73.9	68.6	61.0	51.3	45.2	60.8
Maximum.....	77.0	85.0	87.0	95.0	101.0	111.0	110.0	100.0	94.0	80.0	82.0	80.0	111.0
Minimum.....	-3.0	3.0	15.0	24.0	38.0	42.0	47.0	47.0	37.0	22.0	6.0	1.0	-3.0
Fort Stockton:													
Mean.....	47.0	50.6	57.9	64.7	73.5	80.0	81.3	80.2	74.2	65.1	54.5	47.1	64.6
Maximum.....	90.0	95.0	98.0	101.0	107.0	114.0	110.0	109.0	105.0	102.0	96.0	88.0	114.0
Minimum.....	-7.0	6.0	15.0	20.0	29.0	39.0	50.0	46.0	39.0	23.0	12.0	6.0	-7.0
O2 ranch:													
Mean.....	47.4	51.5	55.1	62.9	72.1	78.0	79.2	77.8	72.6	64.1	54.0	47.5	63.5
Maximum.....	82.0	91.0	91.0	98.0	106.0	108.0	105.0	102.0	99.0	100.0	87.0	80.0	108.0
Minimum.....	5.0	14.0	16.0	24.0	30.0	47.0	54.0	55.0	39.0	19.0	15.0	12.0	5.0
Sanderson:													
Mean.....	47.7	49.9	58.2	66.0	75.4	81.7	83.0	82.2	77.2	68.8	57.4	46.4	66.2
Maximum.....	75.0	84.0	88.0	95.0	99.0	105.0	104.0	102.0	99.0	96.0	86.0	75.0	105.0
Minimum.....	12.0	2.0	22.0	30.0	46.0	54.0	49.0	56.0	42.0	26.0	16.0	15.0	2.0
Sierra Blanca:													
Mean.....	48.6	49.0	54.8	64.2	71.1	78.2	79.4	77.3	72.9	63.4	56.5	48.0	63.6
Maximum.....	74.0	78.0	83.0	91.0	102.0	104.0	101.0	100.0	95.0	84.0	88.0	88.0	104.0
Minimum.....	9.0	7.0	18.0	23.0	36.0	42.0	50.0	50.0	40.0	28.0	7.0	13.0	7.0

¹ In Ward County, just east of Pecos.

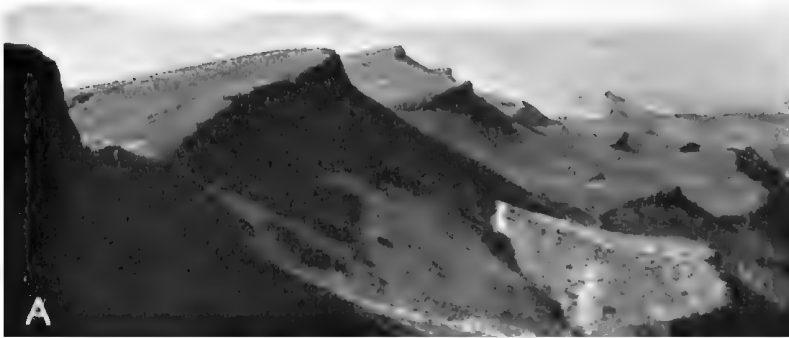
Table 2 gives the mean monthly and annual rainfall and the rainfall of the wettest and driest years at nine stations.

TABLE 2.—Mean precipitation and precipitation for wettest and driest years at Weather Bureau

Station: wettest and driest year		Eleva- tion	Length of record	Janu- ary	Febru- ary	March	April	May	June	July	Aug.
		Feet	Years	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches
Barstow 1.		2,573	16								
Mean.				0.18	0.26	0.44	0.64	0.87	0.79	1.59	
Wettest (1914).				(?)	.50	.02	0	3.93	.75	2.14	
Driest (1917).				.05	0	.05	.05	(?)	(?)	(?)	
El Paso.		3,762	70								
Mean.				.46	.41	.38	.26	.33	.58	1.99	
Wettest (1856).				.33	5.55	2.02	0	0	.58	2.20	
Driest (1891).				.27	.09	.16	0	.38	.40	.06	
Fort Davis.		5,000	65								
Mean.				.50	.44	.38	.56	1.09	1.92	3.27	
Wettest (1875).				0	.80	0	.50	.56	1.34	5.36	
Driest (1871).				(?)	0	(?)	0	(?)	(?)	4.35	
Fort Stockton.		3,050	61								
Mean.				.41	.53	.55	.75	1.41	1.76	1.91	
Wettest (1880).				.14	0	.15	0	.85	1.82	7.27	
Driest (1910).				.24	.22	.17	.39	.52	1.02	.23	
Kent.		4,218	16								
Mean.				.46	.49	.27	.36	.70	1.57	2.14	
Wettest (1866).				1.44	1.14	0	0	1.30	.86	3.11	
Driest (1903).				1.15	.29	.05	.24	.66	4.31	.38	
Marfa.		4,680	5								
Mean.				.15	.41	.47	.69	.53	2.38	2.07	
Wettest (1914).				0	.20	0	.10	.32	4.65	3.09	
Driest (1910).				0	.75	.10	0	1.00	1.30	.20	
O2 ranch.		3,782	10								
Mean.				.62	.47	.36	.38	1.21	1.79	1.29	
Wettest (1920).				1.85	.25	(?)	.15	1.67	.90	1.36	
Driest (1917).				1.12	(?)	0	(?)	.10	.35	.65	
Sanderson.		2,777	9								
Mean.				.48	.25	.18	.70	2.32	1.76	.74	
Wettest (1900).				.78	(?)	.60	.75	4.00	2.50	2.05	
Driest (1901).				.30	0	0	(?)	.40	0	1.10	
Sierra Blanca.		4,512	8								
Mean.				.13	.25	.19	(?)	.64	.66	2.34	
Wettest (1893).				(?)	0	.50	0	2.00	0	1.50	
Driest (1891).				.30	.10	.30	0	1.68	.62	.73	

1 In Ward County, just east of Pecos.

2 Trace.



A, Crest of Tierra Vieja Mountains, down tilted to the east. B, Greatly dissected areas of Rio Grande Gravel Plain. C, Phantom Lake Spring furnishes a large amount of water for irrigating land around Balmorhea.



A, Candelilla, a native plant from which wax is manufactured, on rough stony land of limestone hills. B, Guayule, a native plant from which rubber is extracted, growing on Ector stony loam. C, Shallow stony soils of smoother areas of Edwards Plateau support a considerable growth of lechuguilla with some sotol.



A, Tobosa grass on Verhalen clay. B, Burro grass with mesquite shrubs on Reeves silty clay loam.
C, Sotol and lechuguilla on Ector stony soils in Apache Mountains.



A, A high grassland valley of Davis Mountains. B, Grama, with sotol, on Tierra Vieja Mountain (Brites ranch). C, Grass on Davis Mountains showing effects of overgrazing. Range forage is almost entirely removed, and erosion is increased. Soil is Brewster stony loam.

Barstow in Ward County, east of Pecos, and Fort Stockton in the northeastern part of the area represent climatic conditions for the Pecos Plain and Basin; Sanderson for the Edwards Plateau section; Fort Davis for the mountains; Kent, O2 ranch, Sierra Blanca, and Marfa for the intermountain basins; and El Paso for the extreme western Rio Grande Valley and adjacent basin sections.

Precipitation is the most important climatic feature of the area. It is very local in character and varies considerably from year to year in the same localities. It occurs more abundantly, as a rule, in the Davis Mountains and probably in other mountainous areas than in the basins and plains, and the data given show that the lowest rainfall is in the Rio Grande and Pecos Valleys. The mean annual rainfall ranges from 9.14 inches at El Paso to 17.17 inches at Fort Davis, indicating the influence of the mountains. This is reflected in the good growth of native grasses in Davis Mountains and other mountains. The grass is sufficiently abundant in most seasons to provide good range for livestock. Rainfall occurs most abundantly, as a rule, in July, August, and September, though occasionally a large amount falls at other times. Extreme variability of rainfall may be noted in precipitation records for the wettest and driest years at all the Weather Bureau stations, but these variations rarely coincide in any two places for the same year. Rainfall of the warmer months is predominantly of the thunderstorm type. Sometimes several months pass with no rain in any part of the area.

Evaporation of water is rapid, owing to long-continued high temperatures, high elevation, and much bright sunshine. An exposed tank of water at the Texas Agricultural Experiment Station at Balmorhea lost by evaporation an average of 67 inches of water annually for a period of 4 years.⁴

The winters are short and mild, with greater uniformity of temperature than in the plains farther east, owing, it is said, to the lack of sudden changes produced by northers in that section. As a rule, the cold weather of winter is characterized by a steady cool temperature accompanied by much sunshine and no great amount of wind. Fort Stockton in the eastern section of the area has a rather wide range in winter temperature, the extremes recorded being 95° F. and -7°. The summers are characterized by clear hot days and cool nights. The frost-free periods range from 196 days at Fort Davis to 243 days at Sanderson. Fruit is sometimes injured by late spring freezes.

Table 3 gives frost data for various parts of the area.

⁴ Unpublished records, Texas Agricultural Experiment Station.

TABLE 3.—Frost data from weather bureau stations in the trans-Pecos area, Texas

Station	Killing frosts				Average length of frost-free season
	Average date of last	Average date of first	Date of latest	Date of earliest	
					<i>Days</i>
Barstow, ¹ Ward County.....	Mar. 28	Nov. 1	Apr. 17	Oct. 19	218
El Paso, El Paso County.....	Mar. 18	Nov. 14	Apr. 26	Oct. 27	241
Fort Davis, Jeff Davis County.....	Apr. 2	Oct. 15	May 2	Oct. 1	196
Fort Stockton, Pecos County.....	Apr. 1	Nov. 10	May 7	Oct. 18	223
Kent, Culberson County.....	Mar. 29	Oct. 22	Apr. 12	Oct. 9	207
O2 ranch, Brewster County.....	Apr. 3	Nov. 10	May 7	Oct. 19	216
Sanderson, Terrell County.....	Mar. 12	Nov. 10	Mar. 25	Oct. 19	243

¹ Just outside the area.

AGRICULTURE

The trans-Pecos area, with a very large proportion of land too rough for cultivation and with insufficient rainfall to produce crops even on the best soils without irrigation, is not a highly developed agricultural region. Small areas of farm land, watered by primitive systems of irrigation by Indians and Mexicans along Rio Grande were found by the pioneers.

With increased settlement by whites, more of the land was brought into cultivation along the Rio Grande, some large irrigation systems were developed, and today the greater part of the alluvial land along Rio Grande and Pecos River is irrigated. In recent years other comparatively small areas, where irrigation water is available, have been opened up for farming. Important areas are farmed by irrigation from springs near Fort Stockton and Balmorhea, the latter area obtaining additional water from a reservoir collecting storm water from Davis Mountains. Small tracts are farmed with irrigation water supplied by wells in the vicinity of Pecos and Fort Davis. Along some creek valleys and on lower slopes of smooth land in various sections of the area, Mexicans cultivate small patches of land and irrigate by diverting run-off storm water over the land (tem-porales) by means of artificial banks and ditches.

Table 4, compiled from the 1930 census report, gives the number of farms, the total land area, the acreage of crop land, and the percentage of crop land, by counties.

TABLE 4.—Number of farms, land area, and acreage and percentage of crop land, by counties, in the trans-Pecos area, Texas, in 1929

County	Farms	Area of county	Crop land	
			Acres	Percent
Brewster.....	287	3, 798, 400	5, 983	0. 158
Culberson.....	52	2, 423, 680	66	. 003
El Paso.....	1, 263	690, 720	61, 488	10. 409
Hudspeth.....	194	2, 957, 440	16, 239	. 549
Jeff Davis.....	99	1, 448, 320	1, 140	. 079
Pecos.....	385	2, 645, 760	16, 673	. 630
Presidio.....	532	2, 439, 680	24, 569	1. 007
Reeves.....	327	1, 779, 840	15, 083	. 847
Terrell.....	141	1, 686, 400	138	. 008

More than 200 years ago Catholic monks from Mexico entered the area with the purpose of locating missions to Christianize the Indians. The livestock brought with them multiplied and scattered over various parts of the area contiguous to the settlements on the rivers. Herds of cattle and horses roamed at will, and, as no market existed, the animals were given little attention, and only such animals were slaughtered as were necessary for local needs of meat and leather (13).

With the opening of trails through the area and settlements of Americans springing up during the middle of the nineteenth century, together with the coming of troops to control Indian depredations, a limited market developed and some ranches were established in various parts, the first in sections now in Presidio, Jeff Davis, and Brewster Counties. The original cattle were long-horned native cattle brought from Mexico. With the advent of railroads and barbed wire, land became largely utilized for cattle ranching, improved breeds of cattle were introduced, and now practically all the land is used for grazing livestock. The southeastern, or Edwards Plateau, part of the area has become more generally used for pasturing sheep and goats, which produce a high quality of wool and mohair, respectively. In some of the rougher, more inaccessible, areas near Rio Grande there are many small herds of native Mexican short-haired goats owned by Mexican settlers.

At the present time (1928) more than 99 percent of the area is used for grazing livestock, and doubtless very little of the land will ever be used for any other purpose. The area is climatically well suited to the raising of livestock and to the production of livestock products, as, under careful management, animals develop rapidly and are comparatively free from diseases and parasites. The various grasses and shrubs comprising the natural vegetation afford grazing and browse for several types of livestock. As grasses of good quality are more abundant in some sections than in others, there are certain areas wherein livestock raising has been more extensively developed. Cattle are raised and grazed in all parts of the area, but, owing to a thicker stand of the more nutritious grasses in Davis Mountains (pl. 4, A) and the adjacent basins and plateaus, more cattle are raised in these sections than elsewhere. The Edwards Plateau part of the area is more largely given over to sheep and goats, there being only a thin grass cover, but the many small trees, shrubs, and herbaceous plants make good pasture for these animals. The livestock industry is in a generally prosperous condition. Other parts of the plateau, lying east of this area, have a more abundant supply of grass and water, and given units of land carry a larger number of livestock than here, but with careful ranch management, such as is generally practiced in the area, the land is profitably used in the livestock industry. The limitations of range forage, owing to a low rainfall and in many places to very shallow stony soils, is overcome to some extent by shifting the cattle to various kinds of range, according to conditions. The very large ranch holdings allow the shifting of livestock to various kinds of range vegetation, according to the seasonal growth resulting from moisture conditions.

Cattle feed largely on grasses and on browse to some extent; sheep, also largely grass feeders, browse more than cattle; and goats derive

more than half their food from browse plants (7). The most nutritious and valuable grasses for livestock within the area are the gramas (pl. 4, B), buffalo grass, curly mesquite grass, and various coarse grasses, of which the broom sages are the most extensive. The gramas abound in the Davis Mountains, Marathon Basin, Marfa Plateau, Presidio Plateau, and to some extent in many other sections, and these grasses have been the basis for the larger development of the cattle-raising industry in these sections. Buffalo grass and curly mesquite grass comprise but a small proportion of the range. They grow mainly in the central and southeastern parts of the area, in places in association with the more abundant gramas. Tobosa grass grows in very thick stands in some of the flat plains and basins, but only when young and tender is it eaten extensively by livestock.

Small trees, such as mesquite and oaks, afford browse in certain sections, and shrubs, largely lechuguilla, sotol, yucca, lote bush, canutilla, catclaw, huajilla, and sumac, afford browse which is eaten to some extent by cattle and sheep and extensively by goats. Some locoweed grows in places, and this constitutes a problem on some ranches where losses of livestock are sustained through poisoning caused by the weed. Specialists employed by the Texas Agricultural Experiment Station and the United States Department of Agriculture are conducting studies of the poison-plant problem at a laboratory near Alpine.

The so-called desert-shrub vegetation, creosotebush and blackbrush, is not eaten by any livestock. Large areas of land have a dominant growth of these plants, and here the grazing is confined to the grasses growing in low places, mainly tobosa grass, tussock grass, saccaton, and burro grass. In some extremely rough mountainous areas the range is inaccessible to cattle, or if accessible it is not supplied with water. Therefore, some areas of this character are not used very extensively, except in the valleys and on the lower mountain slopes.

Many ranches include many thousands of acres, and their size is spoken of in terms of sections (640 acres) rather than in acres. Some ranches include several hundred sections of land. According to the 1930 census, there are 320,866 head of cattle (mainly beef cattle), valued at \$16,889,505, in the trans-Pecos area.

Much attention has been given to improving the quality of range animals by using purebred bulls, and most of the cattle are of high-grade Hereford stock (pl. 5, A). The young cattle produced are vigorous and healthy, with a physical make-up that facilitates rapid fattening. The production of especially good cattle for feeding is sponsored by an association in Davis Mountains and adjacent sections, with the result that animals produced here are in great demand by feeders in the Northern States. Though the range is large, most of it is fenced into convenient pastures, and a good supply of water for the cattle is maintained by wells and reservoirs. The native grasses and shrubs afford grazing the year round, except in some very dry years when the range may become so scant that livestock may have to be shipped from some parts of the area to outside pastures. Many ranchers feed a small quantity of cottonseed cake to some of the cattle during the winter or in very dry seasons. It is

reported generally that some feeding is done by ranchers an average of about 2 winters in 7. Condition of the range determines the question of feeding cattle, and as grass is sometimes scant the matter of range management is important, in order to prevent overstocking (pl. 4, C). No feed is grown locally for ranch livestock. No artificial shelter is given range cattle, as the rough character of much of the land provides sufficient natural shelter to prevent the cattle from suffering from severe exposure in the winter.

Many ranchers sell their cattle as calves from 7 to 9 months old, some hold and sell at about 1 year old, and some hold steers to the age of 2 or 3 years before selling. Some ranchers do not raise all their livestock but buy and ship in steers to graze. Most of the calves and yearlings are sold to feeders in Kansas, Nebraska, Missouri, Oklahoma, Minnesota, and Wisconsin, and some are sold in the Eastern States. Steers are marketed mainly in Kansas City and Fort Worth, and some are shipped to El Paso or to California markets.

There is a great variation in the amount of range land required to sustain cattle in this area, depending largely on the character and amount of natural vegetation, the seasonal moisture conditions which govern the supply of water for livestock, the growth of range plants, and the care given to prevent overstocking the carrying capacity of the range. Some of the best grassland, such as that in the Davis Mountains and some adjacent sections, is reported to carry about 30 head of cattle a section under ordinary conditions of rainfall and management. In some other sections, where grass growth is always slight, as on Rio Grande Gravel Plain, Culberson Plateau, and Pecos Plain, ranchers state that it is not safe to graze more than 10 or 15 head to the section. In the southeastern part of the area, on the Edwards Plateau, cattle are frequently grazed on the same land with sheep or goats. According to ranchers, from 10 to 20 cattle and from 100 to 150 goats are here grazed together on a section of land. It is reported locally that there is a tendency by many ranchers to overstock the range. In dry seasons, when grass is very scant, cattle browse to some extent on various shrubs, such as lechuguilla, mesquite, catclaw, sotol, and yucca.

No dairying is carried on in the area except near the towns, to supply local requirements for milk and butter. El Paso constitutes a large market for dairy products, and most of the dairy cows in the area are kept in the vicinity of that city. The 1930 census reports that dairy products to the value of \$835,513 were produced in the area in 1929, of which \$704,118 worth were produced in El Paso County.

Sheep raising is second in importance to cattle raising. In 1930 there were 703,892 head of sheep, valued at \$3,958,955, in the area, and the value of wool produced in 1929 amounted to \$970,196. Terrell and southern Pecos Counties and parts of eastern Brewster County are the most important sheep-raising sections. There appears to be a decided tendency to extend the sheep-raising industry farther west into Brewster, Jeff Davis, and Presidio Counties, which are largely in the Davis Mountains and contiguous areas. At present (1928) the industry is located largely on the Edwards Plateau and

appears to have spread gradually westward from that part of the plateau lying just east of Pecos River, where large numbers of sheep are raised. Sheep are raised principally for wool but many are sold and shipped as mutton. The principal breed is Rambouillet (14). Sheep and goats appear to be largely displacing cattle in the Edwards Plateau part of the area. Sheep are raised on the open range or on fenced ranches, some of which are several thousand acres in size. From 100 to 200 sheep are grazed on a section of land.

Goats have been raised in many parts of the area ever since it was first settled. The original Mexican breeds are still raised (for meat and milk) in small flocks by Mexicans in some of the rougher parts of the Big Bend Basin, but most of the goats are now of high-grade Angora stock (pl. 5, B) and produce a fine quality of mohair. They are grazed on the open range or on large ranches, several thousand acres in extent, well fenced, and well watered. The industry of producing mohair is confined largely to the same general localities in which sheep are raised, mainly the Edwards Plateau, though some is produced in other parts of the area. Terrell County leads all other counties of the area in mohair production, according to the census, having produced mohair to the value of \$190,739 in 1929. The total value of mohair for the entire trans-Pecos area in that year was \$374,294. The many shrubs (pl. 5, C) of the region afford valuable browse for goats.

With the increased utilization of much of the land for livestock raising and for farming by means of irrigation, some of the land of the area has increased considerably in value, though large bodies are still of moderate or very low value. Large tracts of land comprise State and railroad holdings and have not yet been sold to private individuals. In many parts of the area, such land is leased to ranchers, and local reports state that the yearly rental of this or privately owned land for grazing ranges from 3 to 10 cents an acre and in some places even more. It is reported that some ranch land with a good cover of grass and especially well watered in the Davis-Mountains region leases at prices ranging from 20 to 40 cents an acre, where rented in small tracts. These data were obtained from local sources in 1928. The value of land for livestock raising depends not only on the character and quantity of grass and shrubs, which determine the range capacity, but also on the distance from railroads, character of the surface relief, and convenience of the water supply.

The Texas Agricultural Experiment Station has a substation at Balmorhea, where research projects are carried on in growing crops under irrigation, and a ranch substation near Sonora about 75 miles east of the trans-Pecos area is maintained for investigating problems relating to livestock production.

Table 5, compiled from the census reports, gives the number and value of animals, by counties, in the area in 1930.

TABLE 5.—*Number and value of principal livestock, by counties, in the trans-Pecos area, Texas, in 1930*

County	All live-stock	Cattle		Sheep		Goats	
		Number	Value	Number	Value	Number	Value
Brewster.....	\$5, 123, 012	81, 978	\$4, 249, 387	58, 152	\$388, 977	55, 985	\$241, 769
Culberson.....	1, 986, 858	35, 287	1, 800, 804	19	107	2, 930	12, 892
El Paso.....	762, 529	9, 194	527, 141	1, 940	12, 979	2, 091	7, 778
Hudspeth.....	1, 270, 348	19, 624	1, 118, 241	3, 456	22, 887	2, 015	7, 785
Jeff Davis.....	8, 593, 304	63, 013	3, 353, 186	10, 147	69, 217	9, 014	39, 593
Pecos.....	4, 584, 379	51, 016	2, 651, 499	260, 431	1, 644, 607	13, 997	59, 887
Presidio.....	1, 898, 836	30, 103	1, 551, 838	16, 156	95, 002	21, 300	89, 916
Reeves.....	1, 195, 146	21, 454	1, 095, 251	2, 428	15, 183	1, 884	7, 612
Terrell.....	3, 043, 364	8, 897	452, 158	351, 163	2, 087, 650	86, 010	375, 708
Total.....	23, 457, 776	320, 866	16, 889, 505	703, 892	4, 336, 609	195, 226	842, 935

No great variety of general-farm crops is grown in the area, and the comparatively small amount of land in cultivation is confined to the irrigated farms. The principal areas cultivated are in the larger irrigation projects, and the principal crops grown are cotton and alfalfa. Formerly alfalfa was grown much more extensively, but during the last few years cotton has been very largely taking its place. Small quantities of corn, sorghum, and other feed crops are grown, and very small quantities of wheat and oats are produced in some parts of the area.

According to the census, crops to the value of \$7,273,385 were produced in 1929. In that year 54,418 bales of cotton were produced on 83,128 acres and 52,854 tons of alfalfa on 16,932 acres. Acala is the principal variety of cotton grown, and it is reported that the quality and length of staple is very good. Common alfalfa is grown largely, and some Peruvian is also grown. The alfalfa hay is of very high quality.

Vegetables and fruits are grown in a small way by the farmers, and in the vicinity of El Paso these products are grown rather extensively for the local markets. Some fruits and vegetables are shipped. The vegetables are mainly cabbage, cantaloups, lettuce, onions, tomatoes, beans, sweet corn, watermelons, and peppers, and the fruits are apples, pears, plums, and grapes, which are grown on many small farms along Rio Grande, near El Paso. A few small but well-cared-for apple orchards are in the vicinity of El Paso and in the Davis Mountains (pl. 6, A).

Table 6, compiled from the census reports, gives the total value of all crops produced in 1929 and 1919 and the quantity of the chief agricultural products grown in 1929, by counties.

Commercial fertilizers are not in general use, a small quantity only being used by a few farmers on irrigated land in El Paso, Pecos, and Reeves Counties. Thus far, results have shown some increase of yields through the use of phosphatic fertilizers on alfalfa, cotton, and truck crops, but their use is experimental. The census reports that \$88,338 was spent for fertilizers (including manure and lime) in 1929, and that most of this was used in El Paso and Pecos Counties.

Most of the farm labor is done by Mexicans who are paid at the rate of about \$1.50 a day, without board.

TABLE 6.—*Production of the chief agricultural crops in 1929 and value of all crops produced in 1929 and 1919 in the trans-Pecos area, Texas, by counties*

County	Cotton	Corn	Alfalfa	Hay	Value of all crops in 1929	Value of same crops in 1919
	<i>Bales</i>	<i>Bushels</i>	<i>Tons</i>	<i>Tons</i>	<i>Dollars</i>	<i>Dollars</i>
Brewster.....	206	1,797	12	275	40,137	87,906
Culberson.....			4	4	538	614
El Paso.....	35,458	3,751	32,219	32,520	4,751,311	1,762,016
Hudspeth.....	9,510	125	885	938	974,695	3,160
Jeff Davis.....	20	1,790	233	393	52,676	29,272
Pecos.....	2,212	1,475	11,596	11,712	502,875	1,117,926
Presidio.....	3,812	4,491	1,138	1,228	460,456	102,574
Reeves.....	3,200	320	6,731	6,541	488,532	883,105
Terrell.....		150	36	36	2,165	5,466
Total.....	54,418	13,899	52,854	53,947	7,273,385	3,992,039

The size of farms varies, some farms including only a few acres where truck crops are grown in various places near towns or where small patches are cultivated by Mexicans to produce corn, beans, and vegetables for home and local use. The farms operated for the production of general-farm crops range in size from 50 to 100 acres, and some are much larger. The size of ranches ranges from a few thousand to several hundred thousand acres. In the better grazing areas and in sections especially suited to sheep raising, there is a tendency to subdivide and thereby reduce the size of some of the larger ranches.

According to the census of 1930 the percentage of tenancy in the various counties of the area ranges from 11.5 percent in Culberson County to 70.9 percent in Presidio County. Farms operated by Americans have good buildings and improvements, are equipped with improved types of farm machinery and tools, and have good medium-sized work animals. On some of the Mexican-operated farms, which in many places are merely small patches of land crudely worked, the buildings are more simple, many being built of poles with roofs of thatched grass. Very good homes and improvements are on many of the ranches, but many ranchmen live in the nearby towns and have only such ranch buildings as are necessary for the accommodation of ranch employees who look after the fences, water supply, and cattle in the fenced pastures.

SOILS AND CROPS

The soils of the trans-Pecos area differ greatly not only in their broader general features, but in detailed characteristics. In general, the deeper and less stony soils are inherently productive, but their use for dry farming is limited on account of insufficient rainfall over most of the area and because water for irrigation is not available. All the soils are valuable to some extent for their natural vegetation which is utilized in the raising of livestock.

For the purpose of discussing the soils they are classified, according to the surface relief on which they lie, in the following three groups: (1) Soils of the basins and plains, (2) soils of the alluvial valleys, and (3) soils of the rough highlands.

In the following pages of this report the soils of the area are described in detail and their agricultural utilization and possibilities are discussed; their acreage and proportionate extent are given in table 7; and their location and distribution are shown on the accompanying soil map.

TABLE 7.—*Acreage and proportionate extent of the soils mapped in the trans-Pecos area, Tex.*

Type of soil	Acre	Percent	Type of soil	Acre	Percent
Reeves silty clay loam.....	820, 224	4. 1	Toyah soils, undifferentiated.	223, 488	1. 1
Reeves silty clay loam, deep phase.....	1, 589, 760	7. 9	Gila silt loam and silty clay loam.....	96, 768	. 5
Reeves fine sandy loam.....	428, 544	2. 1	Gila fine sandy loam.....	27, 648	. 1
Reeves fine sand.....	488, 448	2. 4	Anthony soils, undifferentiated.....	96, 768	. 5
Reeves gravelly loam.....	2, 011, 392	10. 0	Rio Grande soils, undifferentiated.....	55, 296	. 3
Reeves very gravelly loam.....	1, 002, 240	5. 0	Alluvial soils, undifferentiated.....	87, 552	. 4
Reeves gravelly fine sand.....	87, 552	. 4	Ector stony loam.....	1, 787, 904	8. 9
Reeves chalk.....	707, 328	3. 5	Ector gravelly loam.....	294, 912	1. 5
Reagan silty clay loam.....	1, 078, 272	5. 4	Rough stony land (mainly limestone).....	3, 594, 240	17. 9
Reagan silty clay loam, shallow phase.....	218, 880	1. 1	Brewster stony loam.....	764, 928	3. 8
Reagan loam.....	398, 592	2. 0	Rough stony land (mainly igneous rocks).....	2, 009, 088	10. 0
Reagan gravelly loam.....	801, 344	3. 0	Rough broken land.....	117, 504	. 6
Reagan fine sandy loam.....	161, 280	. 8	Total.....	20, 090, 880	-----
Reagan gravelly fine sandy loam.....	154, 368	. 8			
Verhalen clay.....	617, 472	3. 1			
Verhalen gravelly clay loam.....	267, 264	1. 3			
Verhalen clay loam.....	235, 008	1. 2			
Verhalen fine sandy loam.....	66, 816	. 3			

SOILS OF THE BASINS AND PLAINS

The soils of the basins and plains are subdivided into three groups called series. The series may be designated as light-brown (Reagan) soils, very light brown (Reeves) soils, and reddish-brown (Verhalen) soils, which for the most part have deep surface soils and subsoils resting on beds of calcium carbonate, either hard or soft, and known as "caliche", and rounded gravel. In places, however, the soils are shallow and contain a large quantity of gravel and caliche fragments. The caliche is practically everywhere present. It consists mainly of calcium carbonate, though in places this may be mixed with calcium sulphate. These soils are low in organic matter, are calcareous, or at least basic in reaction. The heavy members have a granular structure, favoring ready absorption of water, easy cultivation, and unhindered penetration by plant roots. The texture of the surface soils ranges from fine sand to clay, though silty clay loam predominates.

Most of these soils occur in smooth nearly flat areas and are developed from soil materials washed from the mountains and other rough land and superimposed on deep beds of gravel. The surfaces of these soils slope upward from the center, or the axes, of the basins in which they lie to the bases of the surrounding mountains. In the broader basins the slopes are gentle, and the central areas, or axial belts, may be almost level. In the narrower or smaller basins the higher rims in many places are well dissected.

These soils comprise a large proportion of the area (fig. 2), and many of them would be well suited to crop production if water for irrigation could be obtained. They are utilized mostly for the graz-

ing of livestock on some of the natural vegetation which consists mainly of grasses, mesquite, sand sage, yeso grass, saltgrass, creosote-bush, and blackbrush (fig. 3).

REEVES SERIES

The Reeves soils are typical brush-land soils developed under a climate too dry to produce a grass cover. The topsoils are light brown and calcareous. They are underlain by light-brown, yellow, or buff calcareous subsoils, though in places gravel beds or beds of calcium carbonate or calcium sulphate constitute the main part of the subsoils.

Types of the Reeves series mapped include Reeves silty clay loam, Reeves silty clay loam, deep phase, Reeves gravelly loam, Reeves very gravelly loam, Reeves fine sandy loam, Reeves fine sand, Reeves gravelly fine sand, and Reeves chalk. These soils occur in large smooth bodies in many places, and the main areas are shown on the accompanying map. However, on a map of this scale small bodies of soils could not be shown separately, and each area as shown on the map includes small areas of other soils, mainly of the Reeves series.

Reeves silty clay loam.—The surface soil of Reeves silty clay loam is light-brown calcareous silty clay loam from 4 to 8 inches thick. It is underlain by light-brown, yellowish-brown, or buff calcareous silty clay loam which, in turn, is underlain at a depth ranging from 12 to 24 inches by a bed of yellow or white calcium carbonate, or caliche. The caliche is very hard in places. As the soil is granular, it is readily crumbled to a friable condition. On drying thoroughly the surface soil packs into a fairly tight light-gray mass, but it is readily broken into fine clods and grains.

Reeves silty clay loam, with its deep phase, is a very extensive soil. It occupies large nearly flat areas in Pecos Plain, Green Valley, and Salt, Valentine, and Sierra Blanca Basins. The lower parts of Diablo and Edwards Plateaus, as well as many of the smaller basins and valleys of the area, include bodies of this soil.

The principal use made of this soil is as pasture for livestock, mainly cattle. As the natural vegetation is largely of the desert-shrub type, mainly creosotebush and blackbrush, with very little grass, the range afforded is slight. The small sparse growth of burro (pl. 3, B) and tobosa grasses affords little nutritious feed, though in low places saccaton, tussock, and similar bunch grasses afford some additional forage, and on some flats where the soil contains a comparatively high percentage of soluble salts local patches of saltgrass and a scattering of chamiso (pl. 6, B) constitute additional forage. This is not considered valuable range land, and ranchers report that it will carry about 10 head of cattle on a section of land.

In the small irrigated areas some trouble has been experienced locally by accumulation of alkali salts, mainly sodium chloride. The soil is low in organic matter and high in calcium carbonate. The content of soluble salts differs from place to place. Near Pecos, in Reeves County, field tests with the Wheatstone bridge showed a range of 0.12 to more than 2 percent of soluble salts in the soil, and in places in Pecos County tests showed a range of 0.1 to 1.5 percent in the surface soil and subsoil.

As this soil, together with the other Reeves soils, is brush-land soil, any improvement in its carrying capacity will be brought about mainly, if not entirely, by encouraging the spread of native browsing plants, such as chamiso.

Reeves silty clay loam, deep phase.—A deep phase of Reeves silty clay loam is mapped, in which the chief difference from the typical soil is the greater depth to the underlying caliche material lying at a depth ranging from 3 to 5 feet beneath the surface. Soil of this phase is of greater extent than typical Reeves silty clay loam.

The grass growth on soil of the deep phase is slightly better than on the typical soil. Therefore it is considered more valuable range land. Creosotebush is less abundant, and blackbrush dominates the desert-shrub vegetation. On some low swales extending through areas of this deep soil in Pecos Basin, there is a thin cover of grama and buffalo grasses. In some of the deeper soil areas locoweed is present, and it sometimes poisons cattle. The very thinly scattered shrubs, mainly lote bush, cacti, canutilla, sumac, mesquite, catclaw, yucca, and pricklypear, are browsed on by cattle to some extent. Ranchers report that this deep soil will carry from 15 to 20 head of cattle to the section.

In Reeves and Pecos Counties, the deep phase of Reeves silty clay loam is used to some extent for the production of crops, local estimates giving the acreage as about 10,000 acres, of which about 1,000, irrigated from Pecos River, lie near Buenavista and 3,000 are in Leon Valley west of Fort Stockton.

At Fort Stockton, 5,000 acres are irrigated from springs, and an area, varying from year to year, but at present about 1,000 acres in extent, near Pecos is irrigated largely from wells. Results have been very good in producing crops with the use of water from springs, but there has been some accumulation of soluble salts in the soil where irrigation water is obtained from Pecos River and from wells, in places where no artificial drainage has been installed. It is reported that some wells of very good water are reached at a depth ranging from 20 to 200 feet, and in some places a good supply of water is obtained at a depth ranging from 20 to 35 feet, the soil resting on beds high in gypsum. In these wells the water contains a large quantity of gypsum and some of the more highly soluble salts, in solution.

Reeves fine sandy loam.—Reeves fine sandy loam is characterized by a light-brown calcareous fine sandy loam surface soil from 6 to 10 inches thick, merging below with yellowish-brown, dull-yellow, or buff calcareous fine sandy loam which, below a depth ranging from 20 to 40 inches, is underlain by white caliche, hard in many places, and consisting largely of calcium carbonate. Below the upper few inches of the caliche bed are deep beds of rounded gravel, the upper 2 or 3 feet of which are loosely cemented by calcium. In places, as near Pecos River, small areas are underlain by thick beds of soft calcium carbonate containing much gypsum, and in some areas such beds lie at a depth of 8 or 10 feet beneath the surface. The soil packs hard on drying, but when moist both surface soil and subsoil are very friable and porous.

This soil occurs only in small areas, mainly in Hueco Bolson, Pecos Plain, Sierra Blanca Basin, and Salt Basin. The relief on which it occurs is smooth but somewhat less so than that of Reeves silty clay

loam. The depth to water is somewhat greater, but the quality of the water is essentially the same as beneath the silty clay loam, and where irrigated, crops are the same. The natural forage is a little better than that on the silty clay loam, as the grass is slightly better and the brush contains a somewhat smaller proportion of creosotebush.

Only very small areas of this soil are used for crops in the trans-Pecos area. A small body irrigated from Pecos River, near Imperial produces from one fourth to one half bale of cotton and from 3 to 4 tons of alfalfa hay an acre. Just across Pecos River, larger tracts are successfully cultivated at Barstow and Grandfalls. Naturally, the soil is comparatively free of soluble salts in most places, but in some places that are irrigated from Pecos River a rather high percentage of these salts was found.

Practically all of this soil is utilized for pasturing range cattle. The grass cover, however, is not good. Most of the natural vegetation consists of brush consisting of mesquite, lote bush, yucca, canutilla, tree cactus, and in places small quantities of creosotebush. The grasses and shrubs afford slightly better grazing and browse than those on Reeves silty clay loam.

Reeves fine sand.—Reeves fine sand consists of light-brown calcareous fine sand from 8 to 15 inches deep, merging below with dull-yellow or buff calcareous fine sand which at a depth ranging from 2 to 4 feet is underlain by a layer, several inches thick, of hard white caliche resting on a bed of rounded gravel. In places the fine sand layer is only 10 or 15 inches thick over the caliche, fragments of which occur throughout the soil. In Hueco Bolson much of this soil is red both in the surface soil and subsoil.

This soil is comparatively inextensive. The largest area lies in Hueco Bolson, and smaller bodies are in Sierra Blanca and Salt Basins. The surface ranges from flat to undulating, and this soil occupies the slightly higher positions in the basins. In Hueco Bolson good water is obtained in fairly large quantities from wells ranging from 200 to 400 feet in depth. A characteristic surface feature is the presence of small mounds of fine sand blown up around mesquite shrubs.

Reeves fine sand is not used for crops but is grazed by cattle, though the scant growth of grasses, weeds, and shrubs furnishes poor pasture, and in dry seasons the range forage is very scant. Coarse grasses and some woollyfoot grama grow in places, and a thin scattered cover of shrubs, such as mesquite, yucca, canutilla, sagebrush (*Artemisia*), and creosotebush, together with chamiso, turpentine weed, globemallow, and other weeds provide some forage.

If irrigated and protected from blowing, this soil would probably produce fair yields of melons, cantaloups, vegetables, berries, small fruits, peaches, and grapes. The probable source of irrigation water would be from wells. The soil appears to contain no large amount of soluble salts.

Reeves gravelly loam.—The surface soil of Reeves gravelly loam consists of light-brown calcareous loam to a depth ranging from 2 to 8 inches. It grades below into yellow or buff calcareous loam. Both surface soil and subsoil contain a rather large proportion of rounded gravel ranging from one half inch to 3 inches in diameter. The gravel are mainly of igneous rocks, with some quartzite, sand-

stone, and limestone. In some included areas the rounded gravel are not present, but there is a large quantity of broken caliche fragments. The subsoil, at a depth ranging from 8 to 24 inches, rests on thin beds of caliche containing a large quantity of the rounded gravel, and below this lie deep beds of the gravel.

Reeves gravelly loam occupies large bodies of undulating or gently rolling land in the Pecos Plain, and smaller areas occur on various other smooth plains and in basins. The soil is very loose and permeable, and water sinks rapidly downward through the porous layers. Possibly in some of the less gravelly spots some kinds of vegetables could be produced under irrigation. From tests made with the Wheatstone bridge, it seems that there is only a very slight amount of soluble salts in the surface soil or subsoil. Water is obtained in wells ranging from 50 to several hundred feet in depth, and, although the water contains a rather large quantity of gypsum and some other salts, it is satisfactory for livestock.

The soil is generally unsuited for cultivation and is used entirely for grazing range cattle. However, very little grass grows, probably not more than a 1 percent cover for the soil as a whole, though in low swales a small quantity of tussock (alkali saccaton) and some other grasses grow. A scattered growth of various shrubs characterizes the soil in most places, together with small amounts of chino, burro, and needle grasses, and *Triodia*, here and there a little grama grass, and in the eastern sections an occasional patch of buffalo grass in low less gravelly spots. Creosotebush is the predominating plant, and large areas occur with little cover but this arid-country shrub which has no value either for grazing or for other uses. Associated shrubs include a few specimens of mesquite, catclaw, yucca, pricklypear, cenizo, chamiso, buckthorn, canutilla (jointfir), and a very few small patches of lechuguilla and sotol. A few of these plants afford a slight amount of browse. Only from 5 to 10 head of cattle to the section of land can be sustained, and most of the scant forage is obtained in the low places where gravel is not abundant and moisture conditions are slightly more favorable for vegetal growth.

Reeves very gravelly loam.—Reeves very gravelly loam is essentially the same soil as Reeves gravelly loam, but it differs somewhat in that the soil mass is composed almost entirely of rounded gravel and the fine-earth content is very slight. In places the gravel are much larger than in the gravelly loam.

This soil occurs almost entirely on the Rio Grande Gravel Plain where it occupies very high ancient terraces bordering Rio Grande. Some of the terraces are in series, rising one above the other to a height of several hundred feet above the river, and they extend up mountain valleys of the smaller tributary streams. In places the smaller streams have cut deep canyons through the gravel beds, and these, together with small valleys and gullied areas, produce a very rough surface configuration.

This soil is unsuited for cultivation and is used only for the scant grazing and browse afforded by the few plants which grow on it. The grasses are mostly the same as those growing on the gravelly loam, but the stand is for the most part even thinner than on that soil. A large proportion of this land is unfenced and is utilized

only for wandering herds of short-haired native Mexican goats and herds of burros belonging to the Mexican residents located in some of the larger valleys.

Reeves gravelly fine sand.—Reeves gravelly fine sand is essentially the same as Reeves gravelly loam, except that the fine earth consists almost entirely of fine sand. It is a soil that is not extensive and is confined to only a few areas in Salt Basin. The land supports practically no vegetation, except an occasional shrub similar to those growing on the other gravelly soils. It is of no value for cultivated crops and has little value for grazing.

Reeves chalk.—Reeves chalk consists of exposed beds of powdery whitish-yellow or cream-colored gypsum (pl. 7, A), calcium carbonate, or a mixture of these materials which occur over large areas of Culberson Plateau and to less extent in Pecos Plain and Salt Basin (pl. 7, B). The surface material, which appears to be of fine or very fine sand texture, becomes slightly compact and hard on drying. It is locally called "gypland". In places a thin layer of silty soil, ranging from one half inch to several inches in thickness, is accumulated on the surface. In such places, as around the salt lakes in Salt Basin, a rather large quantity of soluble salts is in the surface material, as indicated by a growth of salt grasses. The surface relief is undulating or rolling, and on Culberson Plateau it is trenched by both shallow and deep narrow valleys, within which are accumulations of loam soil. Near Ables, in northeastern Hudspeth County, some of the gypsum is in wind-blown dunes from 10 to 20 feet high, and here the material has every outward appearance of fine quartz sand.

In depressions and valleys, wells ranging from 30 to 100 feet in depth furnish a good supply of water which, though containing a rather large quantity of salts, is suitable for livestock. There are some springs in parts of Culberson Plateau.

Reeves chalk is unsuited to crop production, on account of the lack of soil material, and it is used only as pasture for livestock. On account of the very scant vegetation, only from 5 to 15 head of cattle a section can be safely grazed. Although large areas are practically bare, much of the land supports a sparse vegetal cover, ranging from 5 to 20 percent of a complete cover, depending on location. The most abundant vegetation on parts of Culberson Plateau is a wiry grama grass, locally called "yeso grass". It is not highly palatable to livestock, nor is it very nutritious. In associated narrow valleys and depressions where soil has accumulated, there is a fairly heavy growth of tussock grass, saccaton, and various other grasses, such as grama and tobosa grasses, which provide considerable forage. Chamiso and saltgrasses grow in places and provide some forage. Various thinly scattered shrubs, some of which are browsed by cattle or other livestock, include mesquite, sumac, yucca, little buckthorn, agrito, juniper, allthorn, artemisia (sand sage), and cacti.

REAGAN SERIES

The Reagan soils are slightly darker than the Reeves soils. The surface soils contain slightly more organic matter, the normal soils are somewhat more developed and deeper, and they support more of a grass vegetation with little of the desert-shrub growth. The

Reagan soils have brown calcareous surface soils, with lighter-colored calcareous subsoils. The subsoils range in color from light brown to yellowish brown or buff. They merge downward with beds of soft caliche, or calcium carbonate, resting on beds of rounded gravel. Both the surface soils and subsoils are friable and may be readily pulverized. The Reagan soils are comparatively inextensive in the trans-Pecos area. They occur in smooth areas in which moisture is slightly greater than in the Reeves soils, largely in the vicinity of mountain areas, where as a rule the highest rainfall prevails and where surface run-off water from the rougher highlands spreads onto parts of the basin and valley areas and in many places sinks into these soils. The principal bodies of the Reagan soils occur in valleys of the Davis Mountains and in the Diablo Plateau. The vegetal cover ranges from light to comparatively dense, in some places being probably as much as 75 percent of a complete cover. It consists mainly of grasses, predominantly grama grasses, with some needle, burro, tobosa, curly mesquite, and, in eastern parts of the area, buffalo grass, where moisture conditions are especially favorable. A few shrubs and woody plants grow, including mainly small mesquite trees, yucca, mariola, buckthorn, lote bush, and canutilla. In places sacahuiste grass is abundant.

The soils of the Reagan series mapped in the area include Reagan silty clay loam, Reagan silty clay loam, shallow phase, Reagan gravelly loam, Reagan fine sandy loam, Reagan loam, and Reagan gravelly fine sandy loam. The silty clay loam is the most extensive soil of the series.

On large ranches, practically all these soils are used for pasturing livestock, mostly cattle. In some of the valleys where the silty clay loam is deep small quantities of sorghums and other feed crops, including Johnson grass, are grown under irrigation with run-off water diverted from higher slopes by low banks constructed to conform to the condition and slope of the land. Such areas under irrigation are locally called temporales.

Reagan silty clay loam occupies good-sized areas in Hudspeth County, in northern Brewster County, and in Presidio County and occurs to less extent in Jeff Davis and Pecos Counties. Many bodies too small to show on the soil map lie in the various basins and valleys in these and some other counties. The shallow phase of the silty clay loam occurs in small areas associated with the typical soil, mainly in northern Brewster and Presidio Counties. The gravelly loam occupies a rather large area southwest of Marfa on the Presidio Plateau, a few small bodies are on Marfa Plateau, and some small bodies are in the basins of the central part of the area. The fine sandy loam occurs mainly on Marfa Plateau in northern Presidio County and on Diablo Plateau. The gravelly fine sandy loam occurs in extensive bodies in the northwestern part of the area.

Good water is obtained from wells in many places on these soils at a depth ranging from 25 to 400 feet. On the gravelly loam, wells may have to be bored 700 feet deep to obtain good quantities of water, though limited quantities are obtained in shallow wells in the narrow valleys.

The best stands of grass grow on the gravelly loam, and here much sacahuiste affords valuable forage. This plant is present in small amounts on the other Reagan soils but is very abundant on the

gravelly soils. The areas of shallow soil are the least valuable for grazing, as the grass growth is very thin. Various shrubs afford a slight amount of forage. The gravelly loam and silty clay loam soils are reported to carry from 20 to 30 head of cattle or from 100 to 200 head of sheep to the section during years of normal rainfall. Occasional dry seasons shorten the range and reduce its grazing capacity. Locoweed grows in places on these soils.

Reagan silty clay loam and Reagan fine sandy loam are suited to the production of various crops, provided moisture conditions are favorable. All the soils appear to be free of dangerous quantities of soluble salts that would injure plant growth.

Reagan silty clay loam.—Reagan silty clay loam is a brown or grayish-brown calcareous silty clay loam from 6 to 12 inches thick, underlain by light-brown, light-yellow, or buff calcareous silty clay loam or clay. With increase in depth the subsoil becomes increasingly lighter in color and more calcareous. At a depth ranging from 3 to 6 feet it merges with or rests on soft calcium carbonate (caliche) or very calcareous chalky clay, of varying thickness, which in turn overlies beds of rounded gravel (pl. 8, A). The soil is slightly sticky when moist but on drying is easily crushed. The content of organic matter is low, but it is higher than in the Reeves soils.

Reagan silty clay loam, shallow phase.—Reagan silty clay loam, shallow phase, differs from the typical soil mainly in the thickness of the soil layers above the caliche layer. In general, it consists of brown, grayish-brown, or fawn-colored calcareous silty clay loam from 4 to 8 inches thick, merging through lighter-brown silty clay loam or clay into buff or yellowish-brown silty clay loam or clay loam, which rests on hard caliche or gravel embedded in soft caliche at a depth ranging from 15 to 24 inches. As a rule the caliche lying at the slighter depths is hard. In places on higher-lying slopes and ridges, fragments of caliche and stony material as well as some rounded gravel are on the surface and throughout the soil, and the caliche layer, lying from 10 to 20 inches beneath the surface, consists of white concretions of calcium carbonate with some angular and platy caliche fragments.

Reagan loam.—Reagan loam occurs only in some rather large areas on Diablo Plateau in northern Hudspeth County. Small bodies of Reagan gravelly fine sandy loam are included. The surface soil is light-brown calcareous loam from 4 to 8 inches thick. It is underlain by a subsoil of whitish-brown or buff calcareous loam which is somewhat heavier than the surface soil and, at a depth ranging from 10 to 24 inches, rests on a bed of hard white caliche ranging from several inches to several feet in thickness. This layer, in turn, overlies either a bed of rounded gravel, or, in places, limestone strata. The soil naturally packs rather hard on drying but is easily broken up to a friable condition. Although both surface soil and subsoil contain a large quantity of calcium carbonate, there is no evidence of a high percentage of soluble salts.

Reagan loam is dominant on a high gently rolling plain dissected by numerous shallow dry drainage channels (draws), along which the steeper slopes comprise but a small percentage of the generally undulating and gently sloping areas. A number of small plateaus and mesas with steep stony escarpments rising 100 or more feet above



A, Hereford yearling steers, raised near Alpine in Davis Mountains, on the way to shipping pens. B, High-grade Angora goats on Edwards Plateau. C, Cenizo and other shrubs on Ector stony soils comprise good browse plants for sheep and goats.



A, Irrigated apple orchard on Toyah soils, undifferentiated, near Fort Davis in narrow valley of Davis Mountains. B, Chamiso, a characteristic coarse plant on alkali spot on Reeves silty clay loam in Salt Basin. C, Chino grass on Reeves gravelly loam.



A, Dune sand of gypsum (Reeves chalk) in Salt Basin. Sand grains are composed entirely of gypsum. B, Salt Lake surrounded by gypsum (Reeves chalk) in Salt Basin. C, Toyah soils, undifferentiated, in narrow valley of Davis Mountains.



A, Profile of Reagan silty clay loam. B, Profile showing hard caliche beneath Verhalen clay.

the level of the plain are capped by layers of limestone on which the soil is rather shallow in places.

Reagan loam supports a fairly good growth of grama grasses, amounting locally to approximately a 75 percent cover which is much better than that on the Reeves soils. Locally there is an imperfect cover of small desert shrubs consisting of creosotebush and blackbrush. The dominant grass is woolly-foot grama, with some blue grama, black grama, and in spots burro grass and tobosa grass.

None of this soil is in cultivation, and it is all utilized for pasturing range cattle, as most of it is included in large ranches far from railroads. The soil is considered very valuable for cattle raising and grazing on account of the fairly abundant growth of nutritious grasses, though in some years the range is shortened by lack of rain. Many steers are grazed on the land, and some cattle are sold as calves or yearlings. It is reported that the land ordinarily sustains from 15 to 20 head of cattle to the section.

On account of the low rainfall, this soil could be farmed only with irrigation. However, little water is obtained from shallow wells on the Diablo Plateau, and ranchers have to drill wells to a depth ranging from 1,000 to 1,200 feet to obtain a good supply of water for livestock. Water is pumped from these wells by large engines and distributed by pipes into tanks. Some earth tanks, constructed in the shallow valleys to accumulate rain water are dry much of the time.

Reagan gravelly loam.—To a depth ranging from 6 to 10 inches Reagan gravelly loam is brown calcareous loam or fine sandy loam containing a very large quantity of rounded gravel ranging from less than 1 inch to 3 inches in diameter. The gravel content comprises from 25 to 70 percent of the soil mass. Except where exposed at the surface the gravel are coated with a thin layer of calcium carbonate. In places the surface soil contains some small hard caliche fragments. The subsoil consists of rounded gravel embedded in white caliche, in most places cemented into a hard mass. The caliche extends downward to a depth of 2 or 3 feet into the gravel beds which are many feet thick. The gravel are mainly from igneous rocks, though some are from sandstone, limestone, and quartzite. In places small hills and dikes of igneous rocks project through the gravel to the surface and give rise to small areas of Brewster stony soils that are too inextensive to show separately on a map of the scale used.

Reagan fine sandy loam.—Reagan fine sandy loam consists of light-brown calcareous fine sandy loam to a depth ranging from 6 to 8 inches. The material in this layer merges below into light-brown or yellowish-brown calcareous material ranging in texture from fine sandy loam to clay loam, which passes at a depth ranging from 20 to 36 inches into buff or cream-colored highly calcareous fine sandy loam or clay loam, containing concretions of calcium carbonate and fragments of hard caliche, with some small gravel coated with calcium carbonate. At a depth ranging from 4 to 6 feet, beds of rounded gravel occur, which contain calcium carbonate material either as a coating on the gravel or in sufficient quantity to cause a slight cementation of the gravel. Included areas not shown on the map are a shallow phase of Reagan fine sandy loam, wherein hard caliche or caliche-cemented beds of gravel lie at a depth ranging

from 12 to 24 inches beneath the surface and in places outcrop on slopes.

Reagan gravelly fine sandy loam.—Reagan gravelly fine sandy loam has a light-brown calcareous fine sandy loam surface soil about 8 inches thick, which grades below into yellowish-brown fine sandy loam resting on caliche beds at a depth ranging from 12 to 18 inches. Both surface soil and subsoil contain many small hard fragments of broken caliche.

This is an inextensive soil, occurring only on the high smoothly rolling or undulating parts of Diablo Plateau in northern Hudspeth County.

The land supports a moderately abundant growth of grama grasses, in places amounting to a 50 or 75 percent cover of the surface. Except in unusually dry seasons the soil is reported as having the capacity to support from 20 to 30 head of cattle to a section.

VERHALEN SERIES

The Verhalen soils have chocolate-brown or reddish-brown calcareous surface soils and dull-red calcareous subsoils underlain by pink or red clay resting on calcium-carbonate caliche or highly calcareous clay, representing the caliche layer. This material is superimposed on beds of rounded gravel. Four soil types of the Verhalen series, Verhalen clay, Verhalen clay loam, Verhalen gravelly clay loam, and Verhalen fine sandy loam, are mapped in the area.

The Verhalen soils are utilized mainly for pasturing range cattle on ranches comprising Verhalen, Reeves, and various other soils of the basins, together with some of the mountain and rough-land soils. None of these soils contains an appreciable quantity of soluble salts.

Although not used extensively for the production of farm crops, the Verhalen soils would produce good yields of cotton, grain sorghums, sorgo, and various feed crops if water could be obtained in sufficient quantity for irrigation. Good water is obtained in places on these soils (except on Diablo Plateau) in wells ranging from 100 to 400 feet in depth, but the amount is small.

Verhalen clay.—The 10- to 14-inch surface soil of Verhalen clay consists of brownish-red or chocolate-brown calcareous clay. It merges below with red or reddish-brown calcareous clay which at a depth ranging from 2 to 4 feet changes to pinkish-brown or reddish-brown friable clay containing a large number of soft lumps and particles of calcium carbonate. This material rests on hard white caliche (pl. 8, B) of calcium carbonate at a depth ranging from 5 to 10 feet, and this, in turn, lies on deep beds of rounded gravel, the upper gravel layers being cemented by the caliche. Where the caliche lies deepest, much of it is soft. Both the surface soil and subsoil are of granular structure and can be readily pulverized to a friable condition.

Verhalen clay occurs in some good-sized areas in Reeves and Pecos Counties, in the Pecos Basin near the Davis Mountains. One area, extending from Valentine to near Van Horn, occupies a large part of Valentine Basin. Large bodies of this soil are covered with a thick growth of tobosa grass, giving rise to the name "tobosa flats."

The relief of areas on which this soil lies is, in general, very smooth and nearly flat, and water may stand on the land for a short time

after heavy rains. In other localities the slope is sufficient to allow exhaustive erosion, both of the sheet and gully-forming types.

Very little grass or shrubs, other than tobosa grass, grow on this soil, but a very thin growth of mesquite, catclaw, lote bush, and white brush is present in places.

Verhalen clay is a fairly productive soil and appears to contain no appreciable amount of soluble salts. Under irrigation from wells, small areas in southern Reeves County produce one half bale of cotton and from 3 to 5 tons of alfalfa hay an acre. Much of the land lies favorably for the application of irrigation water, and if sufficient water were provided the soil could be utilized successfully for the production of general farm crops.

Verhalen gravelly clay loam.—Verhalen gravelly clay loam has a red or chocolate-brown clay loam surface soil from 6 to 10 inches thick. It merges below into reddish-brown clay which at a depth ranging from 2 to 4 feet is underlain by beds of loose gravel, the gravel of the upper layers having a coating of white calcium carbonate or in places being cemented by the white caliche. The surface soil and subsoil contain a large quantity of rounded gravel. The fine earth material is calcareous from the surface down to the caliche or gravel beds. There are small areas in which the fine earth of the surface soil is fine sandy loam. Both the surface soil and subsoil are granular in structure.

Verhalen gravelly clay loam occurs in only a few small areas in southern Reeves County and northern Jeff Davis County, and rather large areas are in Marathon Basin where some bodies of loam and fine sandy loam texture are included.

The surface relief is gently rolling, and the land is somewhat higher than the adjacent basin land. This soil lies near the foot of the mountains and is developed from the higher parts of alluvial fans.

Grass on Verhalen gravelly clay loam is less abundant than on Verhalen clay, but shrubs, which include some canutilla, yucca, and other species, are scattered but are more abundant than on the clay. In Marathon Basin considerable catclaw, white brush, and mesquite grow. The chief range forage is tobosa grass which is palatable only when young and green. While the grass is young the pasture is reported to maintain from 10 to 20 head of cattle to the section.

Good water is obtained from wells ranging from 75 to 200 feet in depth. This soil would probably not be very valuable for crops in most places, even where possible to irrigate the land. In Marathon Basin, where considerable reddish-brown soil was included on the map as Verhalen gravelly clay loam, honey of very fine quality is produced on the bee ranches. The chief honey plants here are white brush, catclaw, and mesquite.

Verhalen clay loam.—The surface soil of Verhalen clay loam is red, reddish-brown, or brown clay loam or silty clay loam ranging from 4 to 12 inches in thickness. It is underlain by dark-red or reddish-brown heavy clay loam or clay. Below a depth ranging from 15 to 30 inches, the clay grades into light reddish-brown, buff, or yellowish-brown calcareous clay which is more friable than the material in the overlying layers and contains soft white lumps and particles of calcium carbonate with, in places, some rounded gravel

coated with calcium carbonate. At a depth ranging from 3 to 5 feet the calcareous clay merges into or rests on beds of calcium-carbonate caliche, which, in turn, lies on beds of gravel, the upper parts of which are in places cemented with caliche. The surface soil and subsoil are granular and moderately friable.

Verhalen clay loam occupies comparatively large areas in Valentine Basin and in the valleys in and near Davis Mountains in the vicinity of Marfa and Alpine.

The surface relief ranges from flat to undulating, and in most places the gently inclined slopes are sufficiently steep to allow surface run-off of rain water. Some areas have been injured by both sheet and gully erosion.

This soil is utilized entirely for grazing range cattle on large ranches. The natural vegetation, especially in very flat places, consists of a heavy growth of tobosa grass with some burro and triodia grasses, and in other places some grama and needle grasses grow in association with considerable sacahuiste. Scattered shrubs, including mesquite, buckthorn, yucca, catclaw, and others, afford slight browse. Locoweed grows in places. In some sections near mountains the run-off water from the mountain slopes flows over the surface and provides a good supply of moisture which causes a heavy growth of grama and other grasses. Much of the clay loam is reported to maintain from 20 to 30 head of cattle a section.

Verhalen fine sandy loam.—The 8- to 12-inch surface soil of Verhalen fine sandy loam is red, brown, or reddish-brown loamy fine sand or fine sandy loam which merges below into reddish-brown or dull-red fine sandy loam or fine sandy clay, extending to a depth ranging from 24 to 36 inches. This material, in turn, merges with yellowish-brown clay containing soft white particles of calcium carbonate, or, in places, rests on hardened caliche. At a depth ranging from 4 to 5 feet the caliche rests on beds of rounded gravel. In the basin areas the gravel beds are very thick, but in places on Diablo Plateau they are comparatively thin and rest on limestone strata. In most places both surface soil and subsoil appear free of calcium carbonate above a depth ranging from 24 to 36 inches.

Verhalen fine sandy loam is of slight extent and occurs only in a few comparatively small areas, the largest of which are in the western part of Hueco Bolson and on Diablo Plateau in Hudspeth County.

The surface relief is gently undulating and smooth.

Areas on Diablo Plateau have a 50 to 80 percent cover consisting mainly of several species of grama grasses with a few shrubs, such as yucca, canutilla, and some pricklypear. Areas on Hueco Bolson have a cover of coarse grasses and needle, burro, and other grasses, together with a few mesquite and other shrubs. The carrying capacity for livestock is probably about the same as on Verhalen clay loam.

SOILS OF THE ALLUVIAL VALLEYS

The main agricultural soils of the area are the alluvial soils of the stream valleys. These soils are comparatively inextensive and occupy narrow strips along the streams. They consist of deep layers of soil material washed from eroded upland soils of different kinds,

the material along the larger streams having been brought from mountains and uplands far to the north, and the material along the smaller streams is of local origin, having been washed from the mountains and higher land within the area. These soils are deep, friable, and contain moderate amounts of organic matter. They are readily permeable to water and, with the exception of some of the heavier soil, have fairly good natural underdrainage. The surface in general ranges from flat to undulating.

These soils owe their more general use to the fact that they are conveniently located as regards sources of irrigation water and that their surfaces are favorable to irrigation. The soils are adapted to a wide range of crops and are productive. They differ considerably in texture and color and to some extent in productiveness and suitability for various crops. The character of the original soil material is reflected in colors and chemical constituents, and, based largely on these characteristics, the soils are separated into series and the series further subdivided into soil types, based on texture. These soils, though alluvial, are rarely overflowed, as they have, in most places, been built up high above the streams. Some of them, under naturally poor drainage conditions, contain a rather high percentage of soluble salts, and others have accumulated salts after they have been placed under irrigation, owing to the use of water containing soluble salts, where no provision is made for adequate underdrainage.

These soils occur in small bodies, and on the map the separations shown indicate the dominant soils and not the many small spots of individual soil types. The soil series represented in the soils of the alluvial valleys are the Toyah, Rio Grande, Gila, Anthony, and alluvial soils, undifferentiated, along Pecos River.

The soils comprise the following three natural soil groups: (1) Dark-colored soils, (2) light-brown soils, and (3) reddish-brown soils.

TOYAH SERIES

Toyah soils, undifferentiated.—The dark-colored soils include members of the Toyah series. These soils are confined to alluvium occurring along the small streams originating in the local igneous-rock mountain areas and are therefore made up largely of soil material washed from rough stony land. They occur mainly in the narrow valleys of Davis Mountains, many of which are too narrow to show on a map of this scale, and in the larger basins along streams rising in the mountains. Most of these soils are brown, contain a rather large quantity of organic matter, and are composed of deep layers of soil material overlying beds of gravel. They therefore have good natural underdrainage and no noticeable accumulation of soluble salts.

The Toyah soils, undifferentiated, include a number of soils differing in color and texture, which occur in the valleys of streams flowing mainly from the north side of Davis Mountains. In general, they are brown and calcareous, but they include soils ranging in color to black. The darker soils are usually heavy in texture, and the area of their occurrence is small. Some of these soils are calcareous from the surface downward, whereas others are calcareous in the subsoils only.

The Toyah soils occur chiefly along Toyah Creek in southern Reeves County, and a small area lies near Fort Stockton.

Most areas of these dark-colored alluvial soils are deep and very productive. They lie above ordinary overflow, in places almost at the level of the adjacent upland soils, and they are underlain by beds of gravel which allow good underdrainage. The soils are friable and easily cultivated and, though readily penetrated by water, are not subject to rapid leaching. These soils are subject to infrequent overflow and are rather maturely developed, as indicated in places by a slight accumulation of calcium carbonate beneath the subsoils, but this layer is less well defined than in the surrounding upland soils of the basins.

The dark-colored Toyah soils support a rather heavy growth of grasses and shrubs, consisting of grama, needle, saccaton, tobosa, tussock, and other grasses, and in places small oaks, walnut, willow, mesquite, catclaw, and other trees and shrubs grow. Some areas of these soils afford a large amount of valuable grazing for range livestock (pl. 7, C), chiefly cattle. Other areas, largely included in small farms and in irrigated districts, are not so widely used for grazing.

The dark-colored alluvial soils are valuable agricultural soils. They, together with some of the light-colored soils, are used for crops in Toyah Creek Valley in southern Reeves County, under irrigation from springs and from a reservoir which receives run-off storm water from Davis Mountains (2). The principal crops grown are cotton, yielding from one fourth to 1 bale an acre, and alfalfa, producing from 3 to 6 tons of hay. Smaller acreages devoted to other crops at different periods have produced yields as follows: Corn, 25 to 40 bushels; oats, 40 to 70 bushels; and wheat, 20 to 30 bushels an acre. As a rule the grain crops have done better on the heavier soils, and the sandy and loamy soils have proved better suited to vegetables, fruits, melons, grapes, and berries. In Davis Mountains near Fort Davis some successful apple orchards (pl. 6, A), which are irrigated from Limpia Creek and from wells, are on the Toyah soils. The orchards produce good yields of fine fruit and generally have proved profitable.

Substation no. 9 of the Texas Agricultural Experiment Station is located near Balmorhea on Toyah soils, mainly the fine sandy loam and silty clay loam. According to unpublished records of the work at this station, the average yield of alfalfa is about 4 tons an acre from five cuttings a season, and of cotton about 1 bale an acre, following a crop of alfalfa, but only about three fourths bale or less where there is no rotation with alfalfa. In places on these soils, cotton root rot, a fungous disease, causes much damage to cotton, alfalfa, and some other crops. According to results from irrigation at this substation, Toyah fine sandy loam appears to require much less irrigation water than the silty clay loam, and yields of cotton and alfalfa are slightly higher on the sandy soils. No trouble with alkali in these soils has been experienced as yet, and none is expected, as the water does not contain a large amount of soluble salts, and underdrainage is good.

It is reported that apples do not do so well on the soils in the Balmorhea district as on the higher-lying Davis Mountain areas, owing perhaps to less favorable temperatures or some other climatic

feature. Pears and peaches do well on the irrigated soils around Balmorhea. Small bodies around Alpine are irrigated from shallow wells or from diverted run-off storm water and spring water. These areas produce vegetables, berries, small fruits, apples, peaches, plums, and pears. Some corn and other feed crops are grown on a farm, irrigated from a reservoir holding storm water collected after rains, in northern Presidio County.

Native grasses and Johnson grass are irrigated in a few valleys by run-off rain water diverted from slopes and gullies by constructing dams and banks at proper locations. This practice by a few ranchers results in a very much larger growth of grasses for the use of the range cattle. Some of the narrow valleys of the dark-colored alluvial soils are deeply cut by gullies, and as these increase in size after each rain much of the valuable soil and range vegetation is destroyed. The practice of constructing dams to divert the rain water prevents erosion damage to a great extent.

GILA SERIES

The Gila soils have light-gray, grayish-brown, or light-brown calcareous surface soils underlain by subsoils of much the same color but which in most places comprise interbedded layers of irregular thickness consisting of soil materials of fine sand, loam, silt loam, silty clay loam, or clay texture (12). These layers rest on sand or beds of gravel at a depth of several feet. The Gila soils in the trans-Pecos area are Gila fine sandy loam, Gila silt loam, and Gila silty clay loam. These soils range from a few inches to 3 feet in depth, but as a rule the material below a depth ranging from 8 to 12 inches is composed of layers of soil material of two or more of the above-mentioned textures.

The Gila soils occupy Rio Grande alluvial bottom lands extending from Presidio to the northern boundary of the State. They are extensively utilized for crop production. The land is irrigated with water from Rio Grande, largely that conserved in the Elephant Butte Reservoir about 100 miles north of this area. It is distributed by canals leading from diversion dams along the river, and areas irrigated from this system extend 50 miles or farther down the river from El Paso. At a point several miles below McNary, these stream-bottom soils are confined to very narrow areas and the farmers use irrigation water from the river by pumping or by diverting it into small canals with improvised and rudely built stone or earth barriers extending into the stream (pl. 9, A).

The principal crops grown on these soils are cotton, yielding an average of 1 bale an acre, and alfalfa, producing a total of about 3½ tons of hay an acre from three to five cuttings ordinarily made in a season. Much higher yields of these crops have been obtained by some farmers.

At some places within this area, small bodies of heavy soil are so highly impregnated with soluble salts as to be of low value in their present condition. Drainage would doubtless prove beneficial to the soil in such places. Small areas of the silty soils are utilized for wheat and barley, yielding from 20 to 25 bushels an acre, and oats, yielding about 25 bushels. Some grain sorghums are grown, yielding about 23 bushels of grain an acre, and sorgo hay averages nearly 4 tons.

Intensive farming is practiced on these soils in that part of the Rio Grande Valley extending from the north border of the State to a point more than 50 miles south of El Paso. Below that point individual small farms produce mainly cotton and alfalfa, with some vegetables for home use. The soils in the section around El Paso are very high priced, owing to the nearness of shipping points and markets for farm produce.

These soils, although naturally very productive, respond well to the application of organic matter and to a systematic crop rotation, especially where alfalfa is grown part of the time. Some commercial fertilizers have been used by farmers, and the general opinion prevails that applications ranging from 200 to 400 pounds of superphosphate (acid phosphate) to the acre are profitable for all crops when good prices are obtained for farm products.

Gila soils in a virgin condition support a natural growth of small trees and shrubs, mainly mesquite, tornillo, cottonwood, and tomatillo, with some tussock grass. On the heavier soils chamiso and saltgrass are common. These plants afford fair grazing and browse for range cattle.

It is estimated that cotton is grown on about two thirds of all the land of Rio Grande Valley that is in cultivation within the area, and alfalfa is the next most extensively grown crop. The length and quality of the staple of cotton produced on these soils is said to be exceptionally good, and the crop commands a rather high price.

The Gila soils occupy a rather small total area, and owing to the small scale of the map only two divisions of these soils are shown. Soil areas shown on the map as Gila silt loam and silty clay loam include small areas of Gila clay, and areas shown as Gila fine sandy loam include some areas of Gila fine sand.

Gila silt loam and silty clay loam.—Gila silt loam consists of light-gray or brownish-gray smooth-textured silt loam, ranging in depth from 12 to 40 inches, underlain by soil layers of various texture. It is one of the most extensive soils in the Rio Grande Valley. Closely associated with the silt loam is Gila silty clay loam in which the thickness of the surface soil over the variable-textured subsoil strata ranges from 6 to 15 inches.

Small included areas of Gila clay occur in a few small depressions adjacent to the upland. The surface soil in these depressions is slightly darker, being brown or chocolate brown to a depth ranging from 15 to 30 inches, where the material is underlain by the variable-textured strata.

Areas of Gila silt loam and silty clay loam are somewhat flat, and in places the use of large quantities of irrigation water has resulted in a high water table and a high content of soluble salts. Some of the included areas of clay texture have poor underdrainage resulting in a rather high accumulation of salts. Some very low areas of these soils near the river have a high water table and are locally known as "playa land."

Gila silt loam and silty clay loam are considered very productive soils for cotton, alfalfa (pl. 9, B), and sorghums. In the vicinity of El Paso rather large quantities of vegetables, melons, fruits, cantaloups, and berries are grown for local markets, and some of these products are shipped to outside markets. The fruits grown in the

valley include peaches, plums, apricots, quinces, pears, and some apples. The chief vegetables grown are cabbage, onions, peppers, tomatoes, beans, asparagus, spinach, turnips, and celery.

Gila fine sandy loam.—Gila fine sandy loam consists of light-gray or brownish-gray fine sandy loam to a depth ranging from 10 to 20 inches, where it is underlain by interbedded layers of soil material. It is the least extensive soil mapped in the area. Small included bodies in which the surface soil is fine sand have good underdrainage, and little trouble occurs from a high water table or an excessive accumulation of soluble salts.

Much of Gila fine sandy loam occupies comparatively high bottom positions, has fair underdrainage, and contains no great quantity of soluble salts, except where excessively watered. The land has an uneven bumpy surface, in places requiring much leveling to fit it for the application of irrigation water.

Gila fine sandy loam, together with the small included areas of fine sand, is especially suited to growing tree fruits, cantaloups, melons, berries, and vegetables, and crop yields are good. The included fine sand areas do not yield so heavily as the areas of fine sandy loam.

ANTHONY SERIES

Anthony soils, undifferentiated.—Anthony soils, undifferentiated, comprise light-colored soils in the Rio Grande Valley, that occupy flat narrow benches or terraces from 10 to 50 feet above the first bottoms in which the Gila soils occur. The Anthony soils are composed of soil materials deposited by water when streams were flowing at a higher level, but these soils are now, for the most part, entirely above stream overflow. These soils are very inextensive, but they occupy rather important areas and possibly could be utilized for farming in places where irrigation water could be obtained.

The Anthony soils have light-brown or grayish-brown calcareous surface soils underlain by light-brown or yellowish-brown calcareous subsoils which, at a depth of several feet, rest on beds of loose rounded gravel. Most of the subsoils of the different soils are of about the same texture as the surface soils. These undifferentiated soils include soils of gravelly fine sand, fine sand, fine sandy loam, and clay loam texture. The Anthony soils resemble the Reeves soils in surface appearance, but they do not have the developed caliche layer beneath the subsoils. The Anthony soils occupy high valley positions along Rio Grande from the New Mexico line to Presidio, but the bodies are not continuous, owing to interrupting areas of highland. The largest bodies lie between McNary and El Paso. Below McNary the soils, mainly the clay loam, are confined mostly to covelike areas and benches where local small stream valleys join the Rio Grande Valley.

The surface relief of the areas on which the Anthony soils lie is generally flat, areas of clay loam lying on the most uniformly smooth land and the sandy soils occupying slightly hummocky areas with minor undulations. Some of the clay loam areas are gullied by run-off rain water from higher slopes.

These soils are generally friable and pulverize readily even when very dry. Under irrigation some of them would probably produce moderate yields of cotton, grain sorghums, sorgo, Johnson grass,

alfalfa, vegetables, and fruits, the sandy and gravelly soils being better suited for vegetables, melons, and fruits than for other crops. The cost of lifting water to these soils would be high in many places, though perhaps some special crops would prove profitable. At present the Anthony soils are used only for the incidental grazing and browse of ranch cattle afforded by the scant natural vegetation which consists mainly of mesquite shrubs, chamiso, and a few weeds and coarse grasses, with some creosotebush predominating on the clay loam areas.

These soils appear to contain no appreciable quantity of soluble salts. At the time of the survey (1928) several small patches of fine sandy loam were in cultivation north of El Paso, but crops appeared to be suffering from lack of moisture in locations where no irrigation water was available.

RIO GRANDE SERIES

Rio Grande soils, undifferentiated.—Rio Grande soils, undifferentiated, have light-brown or grayish-brown calcareous surface soils underlain by calcareous subsoils of light-brown or yellowish-brown fine sand, or interbedded layers of fine sand, silt loam, clay loam, or clay. At a depth ranging from 7 to 15 feet are beds of rounded gravel or sand. The Rio Grande soils are practically the same as the Gila soils, but they contain less soluble salts and have a lower water table. Rio Grande soils, undifferentiated, in this area include the loamy very fine sand, very fine sandy loam, silt loam, and silty clay loam.

The loamy very fine sand is very inextensive and occurs only in narrow strips adjacent to the stream. It is light grayish brown and merges at a depth ranging from 1 to 2 feet into yellowish-brown or grayish-brown very fine sand or fine sand several feet thick. The very fine sandy loam is more extensive and occupies areas reaching to or nearly to the river. It is light grayish brown to a depth ranging from 8 to 24 inches and is underlain by light grayish-brown or yellowish-brown loamy very fine sand, fine sand, or layers of both materials interbedded with thin layers of soil material of heavier texture. The silt loam has a 12- to 24-inch light-brown mellow silt loam surface soil underlain by brown or yellowish-brown silty clay loam which, in turn, is underlain at a depth ranging from 2 to 3 feet by fine sand or very fine sand. In places the lower part of the subsoil consists of alternating thin layers of heavy and light soil material. The silty clay loam is light-brown clay loam from 12 to 20 inches thick, underlain by thin layers of light and heavy material.

These soils occupy the narrow bottom-land areas along Rio Grande downstream from Presidio, the silt loam and silty clay loam occurring farthest from the river as a rule. They are of only very slight extent, as no alluvium occurs throughout long stretches of the stream where it flows through mountain gorges, canyons, and deeply dissected rough-land areas. The largest areas lie around Presidio, Redford, Lajitas, and Castolon. The Rio Grande soils occur below the point where Los Conchos River enters the Rio Grande from Mexico. As the waters of Los Conchos River are low in soluble salts, it is probable that the soil material along Rio Grande below the entrance of that stream, which has less soluble salts than above that point, has been influenced by the water and soil sediments supplied by Los

Conchos River. Rio Grande silty clay loam comprises most of the bottom land of some of the larger creek valleys which in all places are very narrow. In this area practically no alluvial soil occurs along Rio Grande below Boquillas.

The Rio Grande soils lie high above the river and have good natural surface drainage and underdrainage. The surface relief is smooth and so nearly flat that irrigation water is readily applied. A very large proportion of these soils is farmed, the silt loam and very fine sandy loam comprising the chief areas of farm land. The areas of these soils in cultivation lie mainly around Presidio, Redford, and Castolon. Some large farms are operated by Americans who pump water for irrigation from the river, and many small farms, operated mostly by Mexicans, obtain water for irrigation by the building of small dams and obstructions out into the streams to divert the water into small canals which carry it to the lower-lying farm lands some distance downstream.

The Rio Grande soils are very productive (1, 9). The chief crops grown on them are cotton, yielding from one half to 1½ bales an acre, and alfalfa, yielding from three fourths to 1 ton of hay at a cutting, 4 or 5 cuttings a season being made. Small quantities of corn, potatoes, vegetables, and melons are grown very successfully for local use. The creek-bottom areas, mainly silty clay loam, occur mostly in the Big Bend section as narrow strips of bottom land ranging from a few hundred feet to one half mile in width, along Terlingua, Cienega, Alamito, Tornillo, and other creeks. Here the moist surface soil is grayish-brown calcareous silty clay loam, but when dry it is very light ash gray. It is from 15 to 24 inches thick and is underlain by light-brown or yellowish-brown silty clay loam, several feet thick, resting on beds of loose gravel. Small patches of this land are cultivated by Mexicans who divert storm water from the ordinarily dry creek beds and from higher slopes by means of dams and embankments. Many families derive their chief foods from the small crops of frijoles, melons, corn, wheat, and vegetables grown on this soil. In a few places along Cienega and Terlingua Creeks, some springs supply small quantities of water used for irrigating small fields. The Rio Grande soils support a natural growth of small mesquite trees, tornillo (screwbean), willow, cottonwood, and many other small trees and shrubs, with some coarse grasses. In places a very thick growth of *Aster spinosis* occurs. Some of these plants afford a moderate amount of grazing and browse for cattle and goats of the local ranches.

Alluvial soils, undifferentiated.—Along Pecos River are narrow areas of light-colored and somewhat red alluvial soils, ranging from one fourth to 2 miles in width. These soils lie high above the river but occasionally are overflowed. The soil materials have been brought from mountain and basin areas of New Mexico and some Red Beds materials are also included. These soils contain rather large quantities of soluble salts in places, owing in part to the fact that the original soil materials contained these salts and largely because Pecos River water contains a comparatively high percentage of them.

Some areas of these alluvial soils have light chocolate-red or dark chocolate-red calcareous surface soils underlain by chocolate-red or

salmon-colored calcareous subsoils (Arno soils). In some places the subsoil consists of sandy layers of a salmon color, in other places of chocolate-red clay extending to a depth of several feet, and in other places it is composed in part of thin layers of fine sand. In some areas the surface soil is dark gray or grayish brown and calcareous, and it is underlain by a calcareous chocolate-red subsoil (Pecos soils). Other areas have an ash-gray calcareous surface soil about 10 inches thick, grading below into a light-gray calcareous subsoil mottled with yellow and rust brown, which, at a depth ranging from 18 to 24 inches, grades downward into chocolate-red stiff calcareous clay several feet thick (Petrole soils). Gypsum crystals occur throughout both the surface soil and subsoil of these areas.

In the trans-Pecos area these undifferentiated alluvial soils occur only along Pecos River where that stream passes through the Pecos Basin, and they comprise all the bottom-land areas along the stream. The soils appear to be very productive, and good crop yields have been obtained in places where the soluble-salt content is not high, but in many places the soils contain rather large quantities of salts owing to lack of proper underdrainage. As the water of Pecos River contains a high percentage of these salts much of the time, in many areas the salt condition is increased by irrigation. Some areas of these soils (Pecos silty clay loam), irrigated with water from Pecos River, have produced from one half to 1 bale of cotton and several tons of alfalfa hay an acre, and other small areas (Pecos clay and Arno very fine sandy loam) have been farmed and irrigated from Pecos River and have produced somewhat lower yields of cotton and alfalfa.

All these soils are flat, and all have insufficient drainage. When adequately drained they would probably produce good yields of many crops after most of the soluble salts have been washed out. The natural vegetation consists of tussock grass, saltgrass, creosote-bush, blackbrush, mesquite trees, and various shrubs, which afford only slight forage for range cattle.

SOILS OF THE ROUGH HIGHLANDS

A very large proportion of the area consists of mountains, hills, and other broken and rough stony areas, on all of which the soils are thin. Although none of the soil is sufficiently deep or smooth to be used for crops, it all, no matter how rough, supports some form of natural vegetation, much of which is of value as forage for range livestock (pl. 4, B). The soils of these areas, even though little soil material is present, differ according to the character of the parent rock. Most of the soil materials wash away about as fast as the processes of rock disintegration take place; therefore, true soil characteristics do not have time to develop.

ECTOR SERIES

The Ector soils consist of light-brown calcareous material from the limestone rocks of the region. On drying, the fine earth, which contains many fine gritty limestone particles, assumes a distinct grayish-brown cast. In crevices and pockets of rocks, where a deep accumulation of soil has taken place, the material is dark. Beneath

the areas having a smoother surface soil and on the rocks or disseminated through broken fragments of deep loose stony material there is a thin layer of white calcium-carbonate caliche which in places coats or slightly binds the loose stones.

The Ector soils occur in large bodies in the trans-Pecos area, chief of which are Edwards Plateau; Glass, Santiago, Carmen, Guadalupe, Delaware, Wylie, Heuco, and Finlay Mountains; and parts of Franklin, Quitman, and Van Horn Mountains, Sierra Diablo, and Rustler Hills. Other smaller rough-land areas, comprising mesas, rolling broken lowlands, and small isolated bodies, occur in many parts of the area. Three separations of the Ector series, Ector stony loam, Ector gravelly loam, and rough stony land (mainly limestone), based largely on the character of surface relief and on the content of stony material, are outlined on the soil map.

Practically all of these lands, with the exception of some of the highest and roughest mountain areas, are used for grazing range livestock including cattle, sheep, and goats (pl. 5, C). The Edwards Plateau section is more largely used for sheep and goats than for cattle. The natural vegetation is not thick in most places, except in the included narrow valleys, and it consists of a very thin growth of grasses, a scattered growth of various shrubs, and in many places a rather heavy growth of small woody plants. The grasses are thickest as a rule on the stony loam and gravelly loam areas. They are mainly side-oats grama, black grama, woolly-foot grama, and blue grama, with some chino grass in the southern, or Big Bend, section. The included valleys support a good growth of the grama grasses, and in the Edwards Plateau section buffalo grass grows in places in the valleys and in places on the smoother Ector soil areas where the soil is comparatively deep. Some sacahuiste grows on the smoother areas of the stony and gravelly loams, and lechuguilla and sotol (pl. 3, C) grow very abundantly in many places. The shrub growth is widely scattered and thin. It includes catclaw, mesquite, ocotillo (pl. 9, C), cacti, *Parosela formosa*, *Viguiera stenoloba*, yucca, pricklypear, mariola, little buckthorn, cenizo, canutilla, sumac, lote bush, salloa, agrito, and others. Huajillo, cenizo, guayacan, guayule (pl. 2, B), and candelilla grow in some of the southeasterly areas. In places in the rougher areas of the Big Bend section many peculiar plants, such as resurrectionplant and *Hechtia texensis*, grow on almost bare rock. Some juniper, pine, and oak trees, and a few buck-eye, persimmon, madrona, coralbean, and other small trees grow in places on the rougher land. The larger pine trees grow on Guadalupe Mountain on the crests of very rough stony land areas.

The Ector soils are used mainly for livestock grazing, though some areas of the higher very rough stony land are inaccessible to cattle and sheep, and some areas are not used on account of insufficient water for the livestock. The range will carry from 15 to 25 head of cattle or from 150 to 200 head of sheep or goats a section in good seasons. Some ranchers report that land on Edwards Plateau carries from 10 to 20 head of cattle, together with 100 to 150 head of sheep or goats a section. In this locality much grass grows in the numerous narrow valleys, and the vegetation on the soils is well suited to cattle as well as to sheep and goats. Good water is obtained in limited quantities from shallow wells in some of the narrow valleys, and

on the higher land of Edwards Plateau it is reached at a depth of several hundred feet.

Ector stony loam.—Ector stony loam consists of a thin layer of light-brown calcareous loam or gritty clay loam from 2 to 10 inches thick, resting on either bedrock of hard limestone or on limestone fragments. The underlying rocks have a slight coating of calcium-carbonate caliche in places, and in some places deep accumulations of broken fragments with small quantities of incorporated soil material are lightly bound with the caliche.

The larger areas of Ector stony loam are on Edwards, Diablo, and Culberson Plateaus; Rustler Hills; and Delaware and Hueco Mountains.

Ector gravelly loam.—Ector gravelly loam is practically the same as the stony loam, except that most of the stones, which consist of angular broken limestone fragments, are less than 4 inches in diameter. Ector gravelly loam is less extensive than the stony loam. It covers rather large areas on Edwards Plateau (pl. 10, A) in Terrell County and in various other sections of less rough relief. Bodies of this soil occupy the comparatively smoother and less stony areas of the sections in which they occur.

Rough stony land (mainly limestone).—Rough stony land (mainly limestone) is a land classification given to the areas of very rough mountain areas of limestone. The Ector soil material is present in very small quantities, but most of the land is very rough and stony, consisting of steep or moderate slopes covered with large quantities of small and large limestone fragments, outcropping ledges, and bare exposures of the bedrock.

BREWSTER SERIES

The Brewster soils are red or reddish-brown soils that have been developed from the igneous or volcanic mountain rocks which underlie many large and small areas in the trans-Pecos area. The soils as here developed are very shallow, and much stony material is on the surface. The less stony and rough areas are mapped as Brewster stony loam, and the others as rough stony land (mainly igneous rocks).

The Brewster soils are highly prized for grazing ranch cattle, on account of the generally good growth of grasses, of which the gramas comprise a very large proportion. The grass cover of Brewster stony loam (pl. 4, C) is heavy after rains, but it ranges from about 10 to 40 percent of a complete cover in the rough stony land areas. Local ranchers report that these soils support from 25 to 30 head of cattle or from 150 to 200 sheep or goats to the section, the stony loam leading and the rough lands carrying slightly less. The many shrubs and weeds, as well as the small trees, afford valuable browse for sheep and goats and to some extent for cattle. Some springs and shallow wells in the valleys provide good water, and on the higher lands some dams constructed in low places form reservoirs which for long periods after rains hold a good quantity of water for the use of livestock.

Brewster stony loam.—Brewster stony loam is red or reddish-brown loam or clay loam, containing much fine gritty rock material and a very large quantity of angular rock fragments several inches

in diameter. The soil in most places ranges from 2 to about 10 inches in thickness. It is not calcareous. It rests either on broken rock fragments or parent bedrock of igneous or volcanic origin. In most places the rocks beneath the soil have a coating of hard white calcium-carbonate caliche (pl. 11, A and B), and in places thin crusts of this material occur on the bedrock just beneath the soil. In cuts extending to a depth of several feet the calcium carbonate fills the cracks and fissures in the solid rock. On a few flat areas on mountain crests the soil consists of dark-brown loam over hard caliche several inches thick, resting on the bedrock.

Most of Brewster stony loam lies in small comparatively less rough hilly and mountainous positions in the Davis Mountains section (pl. 11, C), in Brewster and Jeff Davis Counties. Small scattered bodies are in different parts of Presidio and southern Culberson Counties. Brewster stony loam occurs in association with the mountainous and rough lands made up of igneous rocks consisting of andesite, rhyolite, syenite, granite, diabase, basalt, and similar rocks.

Rough stony land (mainly igneous rocks).—Most of the igneous-rock mountain land is designated as rough stony land (mainly igneous rocks). The soil material is the same as that of Brewster stony loam, but it has very slight quantities of fine earth lodged between the rock fragments and in fissures of the bedrock. Rough stony land (mainly igneous rocks) comprises areas occupying large parts of mountains and hills, rising to a height ranging from a few hundred feet to about 1,000 feet above the surrounding basins. Much of this land in Davis Mountains occurs as broad rolling tablelands deeply cut by canyons and bordered by cliffs with steep talus slopes below.

This class of rough stony land comprises much of Davis, Bofecillas, Tierra Vieja, Cienega, Baylor, Sierra Blanca, and many other mountains. The very rough stony land of Brewster material occupies some of the highest and roughest mountains of the section, which include parts of Eagle, Davis, Chisos (pl. 12, B), Quitman, and Chinati Mountains.

The areas of Brewster soils which include rough stony land (mainly igneous rocks) cover a large part of the trans-Pecos area, and most of the land is used for grazing range cattle, together with some sheep and goats in places. Some of the very stony land is so difficultly accessible for cattle and sheep and water is so scarce in the rougher places that its use for livestock is limited. The included narrow valleys support a heavy growth of grama and other grasses which are a valuable addition to the range forage. As a rule, grass is more abundant on this land than on the rough stony land of limestone derivation.

Rough broken land.—Rough broken land comprises rough eroded and gullied slopes, hills, and basin areas, from which much of the surface soil has been washed away, leaving bare clay exposed in the cut, also broken layers of clay, shale, and other unconsolidated formations. These areas occur mainly near or in some of the larger creek valleys in the Big Bend section. Much of the material consists of old valley-filling sediments which are comparatively free of stony material. The surface is so deeply cut by numerous gullies, and the slopes are so badly eroded that the areas show the typical badland

condition, such as occurs in the Dakotas. Areas of rough broken land are comparatively small, and they lie mostly in parts of Terlingua and Tornillo Creek Valleys. The land is almost bare of vegetation, though a few desert shrubs and scattered clumps of grass grow in places. It is practically worthless.

AGRICULTURAL INDUSTRIES AND METHODS OF SOIL MANAGEMENT

The agricultural industries of the trans-Pecos area include livestock raising mainly, some farming, and very little market gardening, truck farming and dairying near the larger local markets. The chief industry, by far, is the raising of cattle on large ranches, and in some sections the raising of sheep and goats on smaller ranches. Sheep and goats are raised chiefly for the production of wool and mohair, but some, representing the increase in flocks beyond the carrying capacity of the land, are marketed for meat.

Most of the cattle are high-grade Herefords, and in the Davis Mountain and adjacent sections a good deal of attention is given to breeding a high type of beef animal which is in much demand by feeders in the corn-producing States. Ranches range in size from a few thousand to more than 100,000 acres, and much attention is given to fencing and to providing water for the convenient use of the cattle. In the central sections the cattle industry is highly specialized and profitable, owing to the comparatively good growth of grasses, but elsewhere large tracts support such a scant grass growth that a large acreage is required for a rather small number of cattle. The large areas support different kinds of range forage, which differs according to local rainfall and character of the soils, and the ranchers are thus able to shift their livestock according to the best growth of vegetation. On some ranches water is scarce and it is necessary for cattle to travel long distances from their feeding grounds to water.

Most of the cattle are sold as calves (pl. 5, A), though some steers are grazed until they reach the age of 2 or 3 years. Some ranchers raise all their cattle and some buy steers and ship them into the area to graze on the land for a year or two before selling them either to other ranchers for grazing or to feeders in Northern States.

As a rule, the area is comparatively free of livestock diseases and parasites. Some losses are sustained when the cattle eat locoweed. This poisonous plant seems difficult to eradicate. Some ranchers have tried to kill it by having Mexican laborers go over the range and dig it up, but this method of eradication has proved very expensive and generally unsuccessful.

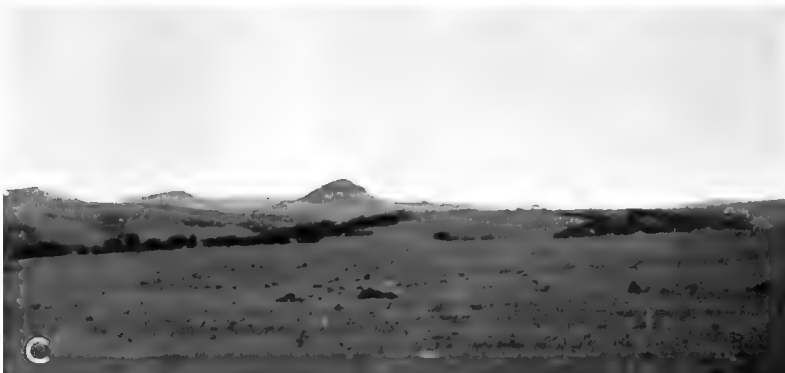
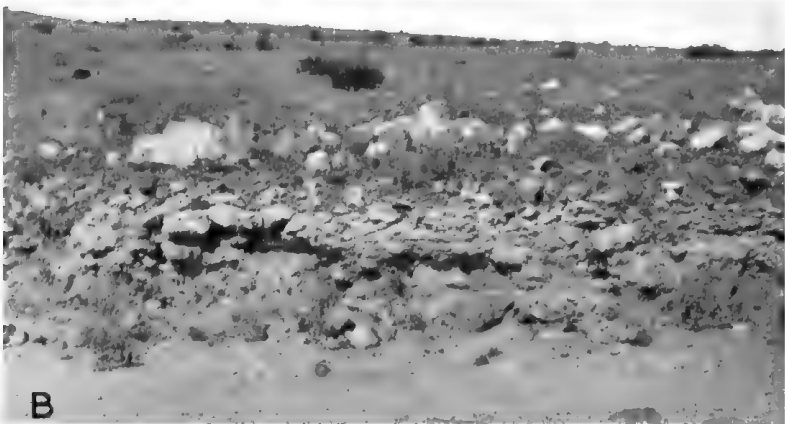
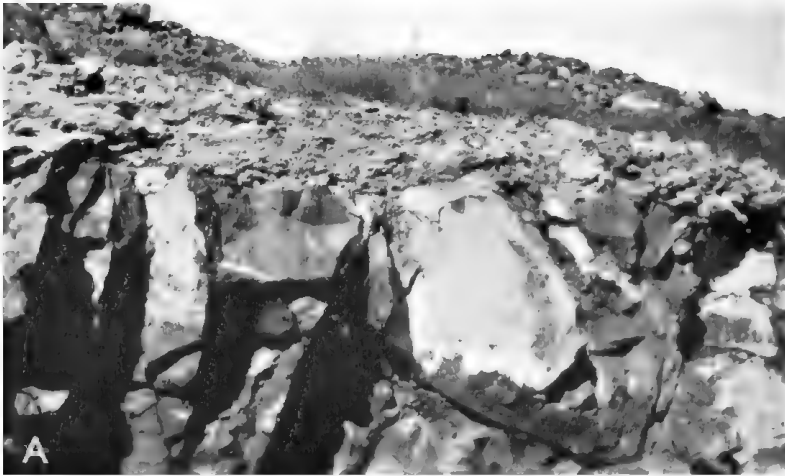
Little attempt is made to grow feedstuff locally, as irrigation is necessary and water in sufficient quantities cannot be obtained over most of the area. Range grasses, and in a few places Johnson grass, have been increased by temporale irrigation with storm water diverted from drainage channels and steep slopes onto the flat grasslands. (Pl. 10, B.) Apparently this could be more generally practiced with profit, and possibly range plants of value suited to the soils and climate could be introduced to advantage. Cattle do



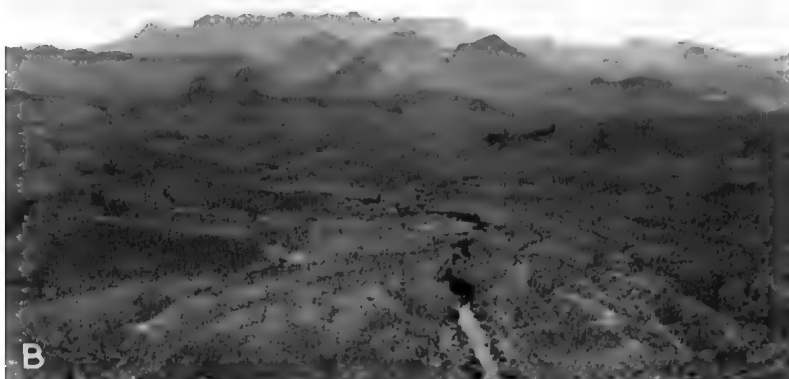
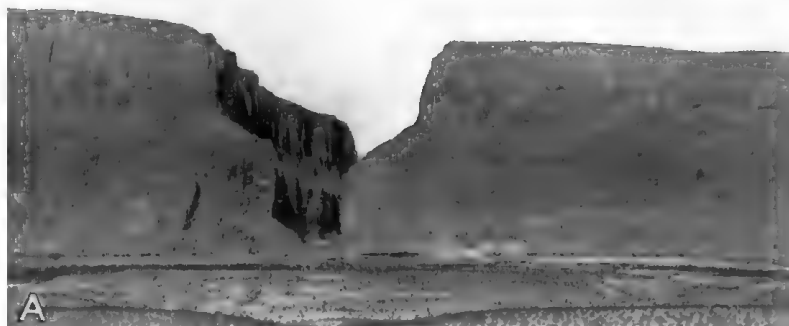
A, Below the organized irrigation districts on Rio Grande many small areas are irrigated by diverting water from the streams by crudely constructed barriers. B, Alfalfa on Gila silt loam near El Paso. C, Ocotillo on rough stony land (limestone).



A, Ector gravelly loam on narrow flat divides of Edwards Plateau. B, Good Johnson-grass pasture grown in a very dry season by diverting run-off water onto smooth land. C, Good growth of grass obtained by constructing a dam across a gully, to keep rain water from escaping, in small valley of Davis Mountains.



A and B, Caliche on igneous rocks at crest of Davis Mountains (Brewster stony loam). C, Brewster stony loam on crest of Davis Mountains.



A, Gorge, 1,600 feet deep, cut by Rio Grande through Mesa de Auguilla in southern Brewster County. B, Chisos Mountains and adjacent foothills. C, Erosion started by wagon trail in narrow valley of valuable grassland.

best on the soils producing the largest quantities of the more nutritious grasses, the gramas being the most abundant in some sections and affording range on which the most intensive cattle production is carried on. Cattle, however, browse on many of the shrubs and woody plants when grass is not abundant.

As a rule livestock are not fed, except in seasons when the natural forage is inadequate, when small quantities of a sustaining ration of cottonseed cake is fed. A few ranchers feed calves and yearlings for short periods, in order to have them in better condition for marketing to feeders, and these fed cattle grow and fatten rapidly and command slightly higher prices. Ranchers report that the range is sometimes injured considerably by overstocking. (Pl. 4, C.)

Farming is done only under irrigation. Large irrigation projects in the El Paso Valley, around Fort Stockton, and around Balmorhea are very successful. As a rule the farms are small and are operated largely by the owners. Some land is farmed along Pecos River and is irrigated from that stream, and small areas in the valleys of Davis Mountains near Fort Davis and Alpine are irrigated from springs, creeks, wells, and run-off water. Some farms in Reeves County are irrigated from wells. Many small areas in the Rio Grande Valley below McNary are farmed by individuals and irrigated by water pumped or diverted from Rio Grande. Small tracts in the larger creek valleys of the area are farmed by Mexicans who obtain irrigation water by diverting run-off rain water onto the land.

The principal crops grown are Acala cotton and common alfalfa, and small acreages are devoted to wheat, oats, grain sorghums, and various other crops. In Rio Grande Valley near El Paso and in Toyah Creek Valley near Balmorhea many vegetables, melons, and fruits are grown. In Davis Mountains near Fort Davis and Alpine some apple orchards (pl. 6, A) are very successful, and the fruit is shipped to outside markets. These orchards are located on the deep soils of the narrow mountain valleys, which are of small extent. The fruits and vegetables are all grown under irrigation. The production of high-quality cantaloups on small irrigated farms in Reeves County has been quite successful.

ALKALI

Rather large quantities of chemical constituents are rendered soluble in water by the processes of rock disintegration and the weathering of minerals into the finer particles from which soils are developed. In a region where rainfall is abundant these soluble constituents are washed down through the soil almost as fast as they are produced from the insoluble compounds, but in a region of very low rainfall, such as the trans-Pecos area, the downward movement of water through the soil is insufficient to carry away the soluble salts rapidly. This is especially true in this area where the water evaporates very rapidly, owing to the high temperature, bright sunshine, and high elevation, and the moisture from below passes quickly upward through the soil and evaporates, leaving the salts at or near the surface. This tendency to concentration is further accentuated in soils where free underdrainage is prevented by a flat surface, heavy soil texture, impervious or very slowly penetrable

subsoil or substrata, high water table, or seepage water accumulated from higher areas. The soluble salts, when accumulated to an amount composing a certain proportion of the soil material, are injurious to plants, and when accumulated in quantities higher than a certain proportion, prohibit any plant growth. The presence of these salts, commonly known as alkali, when in large quantities, are shown by incrustations on the surface and by the absence of plant growth. Some plants are more tolerant to alkali than others, and in most places certain species of native plants, such as saltgrass, are very tolerant, and they indicate the presence of the salts.

Under soil conditions prevailing through most parts of the area there is only a comparatively small proportion of the land which under natural conditions has a high concentration of salts. The chief area thus affected comprises the flat lower-lying parts of Salt Basin (pl. 7, B) in Hudspeth and Culberson Counties, where bare incrustated soils with little or no vegetation lie on deep beds of soft gypsum around a number of large lake beds, the surfaces of which are covered with a thick layer of salts consisting very largely of sodium chloride. At the outer edge of the lower basins the soils having somewhat less concentration are indicated by the vegetation, consisting of saltgrass and other alkali-tolerant plants. (Pl. 6, B.) The chief cause of the concentration of the salts in this basin is that no surface drainage outlet exists. Large areas, mostly mountain land, drain into this basin, and the water stands until it sinks into the soil or is evaporated. Small areas of poorly drained soils, either flat or with slowly penetrable soil material, occur along Pecos River and Rio Grande as well as in some of the flats of the broad basin areas composed mainly of Reeves silty clay loam, and in such positions slow drainage, seepage from higher slopes, and rapid evaporation of soil moisture have produced excessive accumulations of salts on or near the surface, resulting in bare white-incrustated surfaces or a thin growth of salt-tolerant vegetation. Such areas are indicated by appropriate symbols on the map.

The process of salt accumulation is accelerated by the addition of water for irrigation without adequate drainage, the rapidity and amounts of accumulation depending on the quantity of water used, the amount of soluble salts in the water, and the drainage conditions of the surface soils and subsoils. Therefore, with irrigation some areas of soils have developed a high alkali content. Such areas occur on the alluvial soils, undifferentiated, on the Reeves soils irrigated from Pecos River, on some Reeves silty clay loam irrigated from wells in Reeves County, and on some Gila soils irrigated from Rio Grande, in Rio Grande Valley in El Paso, Hudspeth, and Presidio Counties.

Although there are two kinds of alkali, white and black, there is probably no appreciable amount of black alkali in this area as there is a large quantity of gypsum in the soils and in the irrigation water. The white alkali consists chiefly of such soluble salts as sodium sulphate, sodium chloride, magnesium sulphate, and magnesium chloride. Of these, sodium chloride more often occurs in harmful quantities.

Table 8 shows the results of chemical analyses of samples of Reeves silty clay loam, deep phase, occurring in a cultivated field 3 miles west of Pecos, which had been irrigated by water from a well for

several years. Soil samples were taken every 6 inches to a depth of 10 feet.

TABLE 8.—*Chemical analyses of Reeves silty clay loam, deep phase,¹ near Pecos, Texas*

[Parts per million]

Soil material	Depth	Cal- cium carbon- ate	Cal- cium sul- phate	Cal- cium chlo- ride	Mag- nesium carbon- ate	Mag- nesium sul- phate	Mag- nesium chlo- ride	Sodium sul- phate	Sodium chlo- ride
	<i>Inches</i>								
Light-brown silty clay loam	0-6	150	1,501	689	404				1,084
Light-brown silty clay loam with white streaks	6-12	238				134		55	91
Light-brown silty clay loam with white particles	12-18	325				137	44		
Yellowish-brown silty clay loam with white particles	18-24	325	209			21	60		
Brownish-yellow silty clay loam with white particles	24-30	188	70			119	12		73
Do	30-36	313	51			134		2	107
Do	36-42	325	58			116	14		89
Do	42-48	202			19	80		59	91
Do	48-54	213	112			107		137	129
Pinkish-brown silty clay loam with white crystals	54-60	113	6,722			295		272	162
Pink silty clay loam with large amount white crys- tals	60-66	100	9,013			263		43	132
Do	66-72	100	9,490			483		98	124
Do	72-78	113	9,497			644		265	104
Do	78-84	138	9,487			1,046		639	91
Light-brown silt loam	84-90	200	17,028			1,448		570	132
Yellowish-brown silty clay loam	90-96	113	9,696			1,100		128	83
Yellowish-brown very fine sandy loam (compact)	96-102	125	9,854			912		94	272
Do	102-108	113	9,898			1,019		135	228
Pinkish-brown friable silty loam with white crystals	108-112	250	19,164			1,452	217		63
Brown fine sandy loam resting on compact concrete	112-120	100	9,531			483		258	140

¹ Analyses under direction of G. S. Fraps, chemist, Texas Agricultural Experiment Station.

An analysis of a sample of the 1-inch surface crust on Pecos clay, included in the alluvial soils, undifferentiated, on which no vegetation grows, taken 1 mile north of Pecos, shows the carbonate of lime content to be 1,500 parts per million; the sulphate of lime content, 155,456 parts; the magnesium sulphate content, 18,899 parts; the sulphate of soda content, 14,407 parts; and the chloride of soda content, 102,630 parts.

An analysis of a 6-inch sample of soil of the Gila series taken from an irrigated field on which many cotton plants had died, on the farm of W. T. Young in Hudspeth County, showed the following constituents in the soil: Sulphate of lime, 125 parts per million; carbonate of magnesia, 56 parts; carbonate of soda, 225 parts; and chloride of soda, 1,196 parts.

During the course of the soil survey, determinations of the amount of water-soluble salts present were made with the electrolytic bridge on those soils which, if irrigated, could probably be utilized for growing crops. The amount of salts present in each foot was determined to a depth of 6 feet. The location of these tests is shown on the soil map, and the percentages of salts present are shown in fractional form, thus $\frac{2.97}{1.7}$. The upper figure indicates the amount of salts in

the surface foot, and the lower figure shows the average amount to a depth of 6 feet. Sufficient determinations were made to show the range in salt content. It is not to be inferred, however, that no salts are present in locations where no figures are shown. Table 9 shows the total water-soluble salts content for each foot to a depth of 6 feet, and the average content to a depth of 6 feet, at the locations given, with remarks to cover certain conditions, of soils of the Gila, Rio Grande, Reagan, Verhalen, Reeves, and Toyah series, which are mapped.

TABLE 9.—*Water-soluble salts content of several soils mapped in the trans-F*

Soil type	Location	First foot	Second foot	Third foot	Fourth foot	Fifth foot
		Percent	Percent	Percent	Percent	Percent
	5 miles southeast of Clint.	0.09	0.05	0.03	0.04	0.05
	1½ miles west-northwest of San Elizario.	.72	.75	.61	.67	.56
Gila fine sandy loam.	At Ruidosa.	10	18	.18	.16	.17
	1½ mile southwest of Ruidosa.	10	14	.13	.09	.06
	5 miles south of Ruidosa.	27	22	.15	.08	.06
	At Chinati	34	42	.08	.08	.08
	do.	.08	.14	.06	.07	.07
	do.	.14	.03	.03	.06	.06
Gila silty clay loam.	Near Chinati.	12	12	.10	.19	.33
	At Chinati	23	.06	.04	.03	.02
	16 miles northwest of Presidio.	41	.53	.28	.12	.15
	6 miles northwest of Presidio.	18	17	.23	.21	.22
	10 miles northwest of El Paso.	10	.32	.50	.54	.50
	5 miles southeast of Clint.	10	.07	.07	.10	.22
Rio Grande very fine sandy loam. ¹	1½ miles northwest of Fabens.	79	71	.53	.44	.50
	3 miles east of Presidio.	.06	.05	.03	.07	.05
	do.	.03	.02	.03	.05	.02
	At Castolon	.05	.04	.08	.03	.05
	do.	.09	.10	.10	.16	.10
	1 mile southeast of Strobel	.05	.06	.06	.07	.06
Reagan silty clay loam.	5 miles east of Marathon.	.07	.06	.06	.09	.06
Verhalen clay loam.	8 miles south of Fort Davis.	.06	.06	.06	.06	.06
Verhalen clay.	1 mile south of Fort Davis.	.04	.06	.06	.04	.04
Alpine silty clay loam 2.	2 miles south of Lobo.	.09	.10	.09	.07	.07
	6 miles southeast of Fort Davis.	.07	.07	.07	.07	.07
	9 miles southeast of Fort Davis.	.04	.04	.04	.04	.04
Toyah loam 1.	12 miles southeast of Fort Davis.	.05	.05	.10	.15	.20
	5 miles northeast of Fort Davis.	.05	.05	.04	.08	.10
	3 miles northeast of Fort Davis.	18	.37	.30	.28	.24
Balmorhea clay 2.	1 mile northeast of Fort Stockton.	.13	.13	.13	.13	.06
	4 miles northeast of Fort Stockton.	.39	.30	.29	.19	.15
Reeves chalk.	Salt Basin.	.43	.43	.43	.43	.43
Reeves fine sandy loam	1 mile southeast of Imperial.	.53	.53	.44	.33	.27
Reeves silty clay loam.	9 miles northeast of Fort Stockton.	2.80	1.04	.60	.36	.25
	3 miles west of Givrin.	.70	1.22	.90	.58	.58

¹ Mapped with Rio Grande soils, undifferentiated.² Mapped with Toiyah

TABLE 9.—*Water-soluble salts content of several soils mapped in the trans-Pecos*

Soil type	Location	First foot	Second foot	Third foot	Fourth foot	Fifth foot
Reeves silty clay loam, deep phase-----	Salt Basin-----	Percent 0.43	Percent 0.82	Percent 0.86	Percent 0.85	Percent 2.0
	4 miles east of Fort Stockton-----	.07	.09	.07	.07	.0
	6 miles east of Fort Stockton-----	.21	.21	.21	.20	.2
	6 miles northeast of Fort Stockton-----	.10	.10	.10	.10	.1
	6 miles west of Fort Stockton-----	.08	.09	.08	.07	.0
	1 mile northeast of Belding-----	.08	.10	.10	.09	.0
	2 miles northwest of Imperial-----	.91	.03	.44	.35	.2
	1 mile southeast of Buenavista-----	.90	.49	.39	.31	.3
	2 miles north of Buenavista-----	4.00	1.74	.91	.77	.7

These figures indicate a rather wide variation in the amounts of soluble salts in the different soils and within individual soil types in some places. The higher percentages are present in places of poor underdrainage and in some places where overirrigation has caused a high water table and concentration of the salts, whereas in other places sufficient water was not obtainable for proper irrigation.

Many of the soils contain large quantities of calcium carbonate or calcium sulphate, which produce a very light color in the surface layer. These materials, by many thought to be alkali, are not harmful to plants.

The quantity of soluble salts in the soil necessary to injure or prevent plant growth varies according to the kind of salt present, the kind of crop grown, and the type of soil. As a rule, the general farm crops on the heavier-textured soils withstand an accumulation of salts up to 0.2 percent, but on sandy soils they are affected by a much smaller quantity. Forage crops, as a rule, withstand larger quantities of salts than many other crops, whereas legumes, on the whole, are very sensitive, though alfalfa and especially sweetclover are fairly tolerant. Alfalfa, once established, is able to withstand a fairly large salt content, though the very young plants are extremely sensitive and it is difficult for them to live in a soil carrying only moderate quantities of the salts. Oats and wheat are said to withstand fairly large amounts of alkali, and grasses are more resistant than legumes. A concentration of 0.5 percent of total soluble salts is about the maximum limit in which ordinary crops grow and produce profitable yields in the Rio Grande Valley around El Paso (3, 10). Cotton appears to withstand alkali conditions fairly well, and short-staple varieties may grow in soil containing from 0.4 to 0.6 percent of soluble salts.

Although small bodies of the Gila soils have a rather large content of alkali, these soils are farmed and irrigated extensively, with good production of all crops. Overirrigation on the heavier soils, which have slow underdrainage, has resulted in an accumulation of salts that are injurious to crops in some places, but by flooding the land and holding water on it until it sinks through the soil and washes out the salts, a large acreage of land that formerly had a concentration of salts too high for growing crops is now in profitable production. A drainage district in Hudspeth County operates electrically driven pumps part of the time, in order to keep the water table lowered to a depth of several feet beneath the surface.

Some bodies of the alluvial soils along Pecos River and some adjacent areas of Reeves soils through irrigation have accumulated so much salts that crops cannot be grown successfully. As much of the water in Pecos River has been used in irrigation projects above the trans-Pecos area and consequently represents drainage water from soils containing salts, the water, especially at low stages of the stream, is so highly impregnated with salts that it is unsafe to use it for irrigation at certain times, though in times of high water produced by rains the concentration of salts is about the average quantity found at Carlsbad, N.Mex. It seems probable that these soils can be reclaimed by a system of drainage and by flooding the land to wash out the salts. This will probably be feasible after a reservoir has been constructed to conserve the flood waters of the river at some

point above the trans-Pecos area, and such a plan is now being considered. Reeves soils irrigated from wells gradually acquire a concentration of salts injurious to crops, but thorough drainage maintained in these soils would probably prevent such accumulation in most places. At Barstow, just outside the area, a system of drainage has been established and has resulted in preventing serious salt accumulation in some soils of the Reeves series irrigated with water from Pecos River.

According to analyses of Pecos River water, the total dissolved solids at Angeles, near the north border of the area, ranged from 3,370 to 5,920 parts per million throughout a period extending from March 23, 1922, to January 16, 1925. The quantities at Porterville for the same period ranged from 2,044 to 6,000 parts per million; at Barstow, from 1,854 to 6,440; at Grandfalls, from 2,610 to 16,940; and at Buenavista, from 2,640 to 14,350 (5). A large proportion of the dissolved solids consisted of salts harmful to plants.

The water of Elephant Butte Reservoir is used for irrigating the Gila soils in El Paso and Hudspeth Counties, and this water is low in soluble salts as shown by analysis in 1919 at the reservoir, where the average proportion was 41.20 parts per 100,000 (3). Water taken from the canal at El Paso in 1920 showed an average salt content of 61.84 parts per 100,000 during the irrigation period. During the progress of the field work in the trans-Pecos area (in 1927) the content of soluble salts in the water of Rio Grande was determined by the electrolytic bridge in the field. At the north edge of El Paso, below which point several drainage ditches empty into the river, the total salt content was 0.11 percent; at Fabens, 27 miles below El Paso, it amounted to 0.17 percent; and at Ruidosa, about 150 miles below El Paso, it was 0.13 percent. Tests made of drainage water coming from irrigated farms showed the following salt content: 1 mile south of Socorro, 0.18 percent; 1 mile east of Fabens, 0.19 percent; and 5 miles east of Alamo Alto (near Polvo), 0.40 percent.

These analyses indicate that the salt content of irrigation water from the canal at El Paso was about 0.06 percent, a very low amount; but that water from the stream which has received the return irrigation water is much higher, showing that the salts are being washed from the soils where good drainage is provided.

Conchos River, which flows from Mexico, joining Rio Grande near Presidio, contains a much lower content of salts than Rio Grande. Below the junction of these streams the water of Rio Grande showed by bridge tests the following soluble-salt content: 3 miles east of Presidio, 0.04 percent; at Walker ranch, Brewster County, 0.04 percent; and near Castolon, 0.01 percent.

The irrigation project at Fort Stockton receives water from Comanche Springs. A bridge test shows a salt content of 0.15 percent. Water from Phantom Lake Spring showed a total of 0.18 percent and from the spring at Toyahvale a total of 0.14 percent of soluble salts harmful to plants (8). The water from these springs is used to irrigate lands of the irrigation project at Balmorhea. The absence of harmful quantities of salts in the soils of the Fort Stockton and Balmorhea districts indicates good drainage conditions and careful application of irrigation water.

The soils irrigated from wells in Reeves County have in many places showed a gradual accumulation of soluble salts which in places have caused plants to be affected, and some land has been thrown out of cultivation for this reason. Table 10 shows the results of analyses of water taken from wells near Pecos and Saragosa.

TABLE 10.—*Analyses of water from wells near Pecos and Saragosa, Tex.*¹

[Parts per million]

Chemical constituent	Near Pecos	Near Saragosa	Chemical constituent	Near Pecos	Near Saragosa
Carbonate of lime.....	210	200	Sulphate of soda.....	33	302
Sulphate of lime.....	551	308	Chloride of soda.....	1, 113	1, 367
Sulphate of magnesia.....	432	471			

¹ Analyses made under direction of G. S. Fraps.

Water containing salts to this extent should be used very carefully, and good drainage should be provided. Infrequent and heavy applications of water would tend to cause a smaller concentration of salts in the soil than where small quantities of water are applied at frequent intervals.

Thus it is seen that the miscellaneous and private projects derive their water from a variety of sources, such as diverted spring water, diverted surface run-off, diversion of water from the larger creeks and rivers during flood stage, and pumping from wells. The quality of the water used varies from only very slightly salty to very salty. Where salty water is used, such as the water from wells south of Pecos where the salt content is high, the concentration in the soils, especially poorly drained areas on which water is used, gradually increases. Soils irrigated with water diverted from springs, water from surface run-off, and water from the larger creeks during overflow, seem to accumulate little of the salts.

Reclamation of soils high in salts can be effected by draining or leaching, or by a combination of the two. The installation of drainage is necessary on the soils having heavy subsoils, but along Rio Grande many of the soils have subsoils of sand, coarse sand, or gravel, and more or less effective natural drainage is provided where there are adequate outlets. According to local information, the application of 3½ acre-feet of water on Gila fine sandy loam at Chinati, Presidio County, where a layer of porous sand and gravel occurs below a depth ranging from 2 to 3 feet, reduced the average salt content of the soil to a depth of 6 feet from 0.23 percent to 0.08 percent.

The time required for leaching depends on the character of the soil as well as on natural or artificial drainage. The longest time, as much as 6 months in some instances, is required in the heavier types of soil, in those in which a heavy subsoil exists, or in those in which artificial drainage is inadequate. Where good underdrainage is provided, water may be applied constantly to areas around which borders have been erected, in quantities sufficient to keep the area inundated, until from 3 to 4 acre-feet have been added. In some places, especially on the heavier and more poorly drained soils, two applications are generally given, ranging from 1 to 2 acre-feet each,

the second application being made after the first has drained off but while the soil is still moist and before a concentration has been caused in the surface soil by evaporation.

Table 11 is taken from Bulletin 129 of the New Mexico College of Agriculture and Mechanic Arts (3) and refers to the reclamation of an 8-acre tract of silty loam near El Paso.

TABLE 11.—Average content of water-soluble salts, before and after flooding, of an 8-acre tract of land near El Paso, Tex.

Depth	Average content May 10, 1919	Average content April 1920, after application of 1 to 1½ acre-feet of water	Average content May 1920, after application of 2 acre-feet of water
	Percent	Percent	Percent
First foot.....	1.30	0.90	0.20
Second foot.....	.90	1.35	.40
Third foot.....	1.10	.50	.50
Fourth foot.....	.65	.70	1.25

A study of the table shows the reduction of the water-soluble salts in the surface foot from 1.30 percent to less than one sixth of that amount on application of 3½ acre-feet of water in two applications. The first application removed about one third of the salt in the surface foot, leaching it into the second foot. The second application reduced the alkali content of the surface foot to a point where the soil could be utilized agriculturally, the contents of the second and third feet were also materially reduced, and the amount in the fourth foot after the second leaching shows the lowering of the alkali salts into the fourth foot. The total amount of salts in the soil to a depth of 6 feet after the application of 3½ acre-feet of water is only about half of that in the original soil.

It would seem from a review of alkali and water conditions of the area that, on the whole, a rather large amount of water is available for irrigation that is either comparatively low in soluble salts or that is not so high that it cannot be used successfully if applied carefully to soils having proper drainage. The construction of Elephant Butte Reservoir on Rio Grande has provided a large quantity of water fairly free of salts, which is used for successful crop production and for reclaiming land by flooding and leaching the soils that had previously accumulated a large quantity of salts from the river water. It seems that most of the soils of the Rio Grande Valley can be kept free of harmful accumulations of the soluble salts by proper application of irrigation water and by maintaining good underdrainage which should be so designed as to prevent the water table from rising within several feet of the surface. It is probable that irrigation by water from Pecos River, especially on soils with poor drainage, will not be satisfactory in most places until a reservoir that will insure a larger supply of water containing smaller quantities of soluble salts has been constructed. Alkali conditions will probably give trouble on the Reeves and other soils of the Pecos Basin, where water is obtained from wells, unless water is applied very carefully and good underdrainage is provided and maintained.

IRRIGATION

The rainfall in the trans-Pecos area is insufficient for the production of cultivated crops. Sporadic efforts in using small areas for growing crops under dry-land farming have been generally unsuccessful, though occasionally small yields of some crops have been made during especially rainy seasons on the deep soils so situated as to lose little water by run-off.

Irrigation had long been practiced in Rio Grande Valley, first by Indians and later by Mexicans, long before Americans from the United States had settled in the region. As early as 1754, about 3,000 acres of the valley land near El Paso were irrigated by diversion of water flowing by gravity through acequias onto the land farmed by Indians under direction of the Spaniards, and the region was famous for the orchard fruits, grapes, and vegetables that were grown. Irrigation from springs around Fort Stockton and Balmorhea was carried on at a very early period by Mexicans who produced small grains, corn, and vegetables. Irrigation along Pecos River is said to have started about 1890.

A number of important irrigation projects are successfully operating under well-organized systems of management, and individuals in different places farm small tracts of land and apply water in different ways. The largest irrigation projects are in El Paso Valley, extending from the northern boundary of the State as a continuation of the Rio Grande Valley areas of New Mexico irrigated from Elephant Butte Reservoir to a point about 100 miles down the river. The upper part, in El Paso County, is in a district comprising between 50,000 and 60,000 acres of land, nearly all of which is in cultivation, and the lower part, in Hudspeth County, includes about 20,000 acres, of which between 12,000 and 15,000 acres are cultivated. At Balmorhea, in Reeves County, about 15,000 acres are irrigated from springs and a reservoir, a smaller project near Fort Stockton irrigates about 6,000 acres from springs, and in Leon Valley near Fort Stockton 3,000 acres are irrigated from Leon Springs. Several areas along Pecos River use water from that stream. About 3,000 acres of this project are north of Pecos, approximately 1,000 acres are just south of Pecos, and about 4,000 acres are near Buenavista and Imperial. It is reported that sufficient water is available for the irrigable lands in the Rio Grande Valley, but that in the other districts the acreage of irrigated land has about reached the limit of the water available at present. Plans have been proposed for the construction of a large reservoir on Pecos River near the northern edge of this area. This should largely increase the supply of irrigation water for land along the river as well as provide water with a lower content of soluble salts.

Down the river, from a point about 10 miles below McNary on Rio Grande, irrigation water is pumped or diverted from the river by individuals who farm the narrow strips of alluvial soils (pl. 9, A). Small farms are irrigated in a number of counties, mostly in Reeves, Pecos, Jeff Davis, Presidio, and Brewster Counties, by water pumped from wells. In the Davis Mountains a few small springs furnish a little water for local farms and orchards. Temporale irrigation is practiced by a few farmers, mostly Mexicans, whereby storm water is diverted from slopes onto lower areas by constructing

embankments and small ridges of land at proper locations (pl. 10, B).

Organized irrigation was started in El Paso County about 1908, when a large diversion dam was constructed across Rio Grande north of El Paso. Elephant Butte Dam was constructed in 1916, and this reservoir furnishes water for all the El Paso Valley irrigated lands, but prior to the building of the dam only a small area was under irrigation. All the land in El Paso Valley and in the large district in Hudspeth County is now irrigated by gravity flow from Elephant Butte Reservoir, the water being turned into the Rio Grande channel and then diverted to the land by diversion dams across the river channel. Practically all irrigable land is now under cultivation in this district, and abundant water is available at all times.

The water for irrigation in the Toyah Creek Valley district at Balmorhea is obtained from Head Spring and Phantom Lake Spring (pl. 1, C). This water supply is supplemented by flood water diverted from Toyah Creek into a reservoir covering 1,000 acres, and the water from the springs which is not used directly is also diverted into the reservoir. In the growing season water is applied to the land direct from the springs and is supplemented by the stored water in the reservoir. This district is watered entirely by gravity, and farmers are limited in the amount of water used, as they can use water only every 32 days. Sufficient water is usually available, though in seasons of slight rainfall water in the reservoir becomes very low.

Organized irrigation in the Fort Stockton area was begun about 1909. Water is supplied to this district entirely from Comanche Springs and several smaller springs, and at present no water-storage facilities are provided.

Buenavista district was started in 1911, when a reservoir, to be filled by diverting water from Pecos River, was constructed to hold 15,000 acre-feet of water. This project, when first started, included 8,000 acres of land, but in 1928 only about 4,000 acres were in cultivation. The decreased acreage was due to insufficient water, and as a result soluble salts accumulated in the soils. The quantity and quality of water for this district is dependent on the water in Pecos River. If sufficient flood water is available for filling the reservoir, a supply of good water is available. During periods of normal flow, the water in Pecos River becomes high in salt content and is injurious to crops. It is locally reported that the water has been unsatisfactory in character and in quantity available since 1922.

Leon Valley irrigation district was started in 1909 and is dependent on water from Leon Springs. This project was started by selling small tracts, but at present it is largely owned and operated by one man. The normal flow during the winter is stored in a reservoir with a capacity of 4,500 acre-feet, and sufficient water is available for the present acreage under irrigation.

The project on the Pecos alluvial soils north of the city of Pecos was started, on a small scale, about 1890. The Pecos water district was organized in 1907 and is owned and controlled by the farmers. Water for this district is obtained by gravity flow from Pecos River, and as no storage facilities other than diversion dams are provided, insufficient water with some salt accumulation has retarded agricultural development of the district.

In the vicinity of Pecos, artesian water is used for the irrigation of small farms, irrigation water being obtained by pumping from a shallow-water belt. The wells range from 200 to 500 feet in depth, and the water rises to a height ranging from 20 to 75 feet from the surface. The wells yield from 800 to 2,000 gallons a minute, and the amount of water seems to be sufficient for the acreage of land in cultivation.

Small areas are irrigated from springs, by diverted run-off water, and from a few small reservoirs and wells in small valleys of Davis Mountains (pl. 10, C) and other mountain areas. Many mountain valleys offer convenient sites for large reservoirs which might be used to conserve large quantities of run-off water for use on the rich alluvial soils of the narrow valleys.

The cost of water in El Paso Valley is about \$5.60 an acre a year. Of this, \$2.60 is charged for maintenance and operation. The cost is somewhat higher in the Hudspeth County district which lies just below the El Paso County district. The cost in the Balmorhea district is about \$4 an acre a year.

The check system of applying irrigation water is used, whereby small areas are enclosed by low embankments. The fall is confined to about 1 inch to 100 feet on heavy soils and to as much as 2 inches on sandy soils.

SOIL EROSION AND RAIN-WATER CONSERVATION

In a region of such light rainfall as that prevailing throughout the trans-Pecos area, the impression commonly prevails that soil erosion is a matter of little consequence and that ordinary attempts at holding the run-off rain water on the land is scarcely practicable.

However, when it is noted that vast areas of rough lands and some formerly smooth lands have been subjected to most severe washing away by surface erosion resulting in the cutting of deep canyons (pl. 12, A) and numerous valleys, it is realized that soil erosion has been most active. Deep soil cannot be formed on the rough mountain lands, owing to the rapid removal of soil materials during rains, and even very smooth slopes of the basins lose much fine surface soil by the flowing surface water which is heavily charged with silt and clay. The rapid run-off of rain water is attributable to the very steep stony slopes of the rough lands which have no deep beds of soil material to hold the water, and the scant vegetation on the slopes of the basin areas allows the soil mass to become hard, sun baked, and impermeable, thereby preventing rapid absorption, so that the 1- to 2-inch granular surface layers are readily saturated and carried away by each rain. Erosion conditions are very favorable during the summer, when the topmost inch or two of soil is loose and the soil beneath is hard and packed. The largest amount of the annual rainfall occurs during the summer season, and the rains are of the sudden dashing thunderstorm type wherein a large quantity of rain falls within a very short time. These rains, many of them heaviest on the high rough lands, fall rapidly and the run-off water rushes quickly down the steep mountain slopes (pl. 12, B) and passes either into gullies and canyons, which carry the water to the rivers, or onto the smooth moderately descending slopes of valleys and adjacent

basins (pl. 1, B), rushing over the surface to the lowest area and carrying the soil material away, and cutting gullies, which increase in size with every downpour, in the thick soil layers.

Prior to the coming of white men into the area, some of the land was probably covered with a thicker stand of grass which held the soils to fair advantage, but owing to the use of vehicles, which cut shallow grooves in the soils, and the grazing of livestock, which decreased vegetation and trampled the surface into trails, the running surface water has gradually enlarged such places into gullies and gulches, many of them of vast proportions. Many examples of the destructive force of the rapidly flowing run-off water are noted. In places great embankments have been thrown up for miles to protect railroads, in places highways are less substantially protected from costly devastation and destruction, and many beautiful well-grassed small valleys of the mountains are in an advanced stage of erosion caused by the rapid run-off of rain water. The water may first flow down a cow trail or wagon rut (pl. 12, C), then as these become larger and deeper the soil sloughs off in great slabs, many tributary gullies start in every direction working and eating into the higher slopes, and eventually in places a typical badland type of soil deformation has become established, with practically a total despoliation of valuable soil and an almost complete removal of all vegetation. Many ranchers have come to realize the havoc that is being wrought by erosion on some of their best grazing lands.

In addition to the loss of some of the best soil by erosion, the loss of water, which is so valuable in a region of light rainfall, is a matter for serious consideration. The rain water, if held on range land, would materially increase the growth of grasses which constitute such a valuable source of forage for livestock. The effect of incidental water retention in pockets on slopes and in flat areas where run-off is even slightly retarded is evidenced by the luxuriant and thick growth of grasses in many places. Enormous quantities of water from mountain and rough-land slopes pass into gullies and are lost to every use, except as they may furnish water to large streams from which some may eventually be used for irrigation, but much of the water flows to the sea.

Conservation of water in large-project reservoirs, such as that formed by the Elephant Butte Dam in New Mexico and in the one contemplated for Pecos River, is of great importance, but the enormous value in the aggregate of the water lost through the thousands of minor rough-land canyons and smooth-land gullies and draws is ignored. Even a small amount of this run-off water if diverted to smooth grasslands would prove of great benefit to the range pasture land by producing heavier crops of the native grasses. A number of ranchers in the Davis Mountains and contiguous areas have realized the losses caused by run-off rain water, not only in causing soil destruction but in loss of needed moisture for plants, and they have built dams at the heads of gullies and in some places embankments bordering the gullies, thus diverting water from these outlets and preventing the run-off water from causing increased washing. By thus spreading the water over the adjoining valleys they have greatly increased the growth of grasses, thereby enlarging the carrying capacity of the land for range cattle. In other places the banks are constructed at places near the foot of mountain or highland slopes

and are extended, with the proper fall necessary to convey the run-off water, onto smooth areas of grassland. This method, known as the temporale system, is successfully employed by a few progressive ranchers, and there are many areas of valley and basin land where the system, varied to suit local conditions, could be used to conserve water and prevent the loss of much land from washing. The many narrow canyons and valleys in mountain areas provide good sites for the construction of dams which would conserve great quantities of mountain storm water now lost to the region. With this store of water, it would seem that many valleys could be used for the production of feed crops for livestock and even for growing other crops, in places. Much of the valley and basin land would doubtless be protected from erosion and the water conserved and used for the larger production of the natural range forage by the construction of terraces along the contours of slopes.

During investigations of the run-off of rain water and of soil erosion on very moderate slopes at Texas Agricultural Experiment Substation No. 7 at Spur (6), it was found that 20 percent of the total rainfall has been ineffective because it has occurred in light showers that furnish so small an amount of water that it quickly evaporates, another 20 percent was lost as run-off, leaving approximately 60 percent of the total rainfall to be absorbed by the soil. In the trans-Pecos area there is doubtless a very much greater loss through run-off, especially in the mountain areas.

Results at Spur also show that tremendous water losses occur even on areas having very little slope, and that losses of soil by erosion are so great, even on slopes of as little as 1 percent grade, that the soils are in danger of being impoverished rapidly, especially those supporting only a scant vegetal cover.

SUMMARY

The trans-Pecos area includes the nine counties of extreme western Texas, which lie entirely west of Pecos River. The area consists of mountain ranges, isolated large and small mountain and high rough-land areas, dissected high rock plains, and great areas of flat lands of basin and plain physiography. The basins and plains lie from 3,000 to 4,000 feet above sea level, and the mountains rise to more than 8,000 feet in places. The mountain peak, El Capitan, the highest point in Texas, is about 9,000 feet above sea level, and the lowest point in the area, in the extreme southeastern part in Rio Grande Valley, is only about 1,500 feet above sea level.

Settlement of the area is confined principally to land along the railroads, largely within the towns. It is very sparse over most of the area.

The climate is moderate and healthful. The average annual precipitation (mostly rain) is very low. The heaviest rainfall occurs in the Davis Mountains section, where it averages about 17 inches a year, and the lowest around El Paso, where it averages less than 10 inches. The amount of rainfall varies greatly from year to year, but, as a rule, is heaviest in the summer. The mean annual temperature ranges from 60.8° F. at Fort Davis to 66.2° at Sanderson.

A fairly large number of soil types are mapped. The mountains and rough lands, composed chiefly of limestone and igneous rocks,

are stony and rough, with so little soil material that they can never be used for any purpose other than for livestock range. The soils in these rough lands are chiefly of the Ector and Brewster series, and, together with rough stony land, comprise a very large proportion of the area.

The basin soils, developed from old mountain sediments spread over the flat areas of great basins and plains, comprise some brown soils with a grassland vegetation, which are included in the Reagan series; red grassland soils, included in the Verhalen series and very light brown soils covered mainly by a desert-shrub vegetation, which are included in the Reeves series.

Alluvial soils occupy comparatively small narrow areas along the larger streams and are included in the Gila, Rio Grande, and Toyah series.

The smooth-land soils are, as a rule, high in calcium carbonate in all layers, and a layer of accumulated calcium carbonate, characteristic of the soils of the plains or subhumid regions, occurs in the soil profile. Accumulations of alkali salts are confined mainly to some areas of alluvial soils and some of the Reeves soils. This condition has been largely induced by irrigation without adequate underdrainage. Some accumulation of salts occurs in some of the Reeves soils, more especially in locations where the soils are shallow and the underlying parent material contains a large quantity of gypsum.

Most of the basin and alluvial soils are fertile and with sufficient moisture will produce good crop yields. Soils of silty clay loam texture predominate, though there are also large bodies of sandy soils. If sufficient suitable water could be obtained for irrigation, large areas of these soils could be used for producing many kinds of crops. The principal areas farmed under irrigation are the alluvial soils of the Rio Grande and Pecos Valleys, irrigated from Rio Grande and Pecos Rivers; land around Balmorhea, irrigated from springs and reservoirs; land near Fort Stockton and Leon Springs, also irrigated from springs; and small farms in Reeves, Pecos, Jeff Davis, and Brewster Counties, irrigated from wells, small springs, and by run-off storm water. It is estimated that about 140,000 acres are farmed under irrigation, and no farming is possible without irrigation.

The soils are fairly productive, and yields are good where sufficient water is provided and where salts are not accumulated to the point at which crops are injured. Under conditions of slow underdrainage or by using too much or too little water, the salts harmful to plants are in places accumulated to such an extent as to injure or destroy crops. This condition can be, and is, prevented where a good supply of water fairly free of the salts is provided. Cotton and alfalfa are the principal crops grown. Some other feed crops, vegetables, fruits, and truck crops are grown in the vicinity of El Paso.

Most of the land is utilized for grazing livestock, mainly cattle, on large ranches. A very good type of beef animal is produced under range conditions, high grades of the Hereford breed predominating. The most intensive and successful production of beef cattle is in the areas of best grassland which occur in the Davis Mountains and vicinity and in various other mountain and plateau sections.

Sheep and goats are raised extensively in the southeastern, or Edwards Plateau, section. Sheep are mainly high-grade Rambouillet stock, and the goats are Angora grades. Large quantities of wool and mohair are produced. The sheep- and goat-raising industries seem to be spreading westward into the Davis Mountains section. Much of the range land supports a very scant growth of grasses and will carry only 10 or 15 head of cattle to the section of land, but the best grassland will carry about 30 head to the section.

Extensive farming is not likely to develop until larger quantities of irrigation water are provided. In certain sections small tracts of land can be irrigated by pumping from wells. In the mountains many narrow valleys with good soils might be irrigated from wells furnishing a limited supply of water if it could be augmented by conserved storm water from reservoirs. A large reservoir on Pecos River would doubtless provide a large quantity of good water which could be used to irrigate extensive areas. In certain shallow-water belts of some of the basins, water might be used to advantage more largely by pumping onto small farms. All plans for irrigation should be based on the quantity and quality of the water, cost of pumping (if gravity irrigation is not possible), and the character of the soil, with especial reference to both surface drainage and underdrainage.

The price of rough land and mountain land is governed largely by the suitability of the land for grazing and by the water supply; the smooth basin lands and the better grazing gravelly soils of moderate roughness are held at somewhat higher prices; and the better farms of irrigated land in good locations convenient to water and markets comprise the highest-priced land in the area.

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